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PENETRATOR IMPACT STUDIES OF SOIL/CONCRETE

FINAL REPORT

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The terradynamic trajectories of various types of penetrators impacting Eglin sand in a vertical direction is reported on. Included in the studies are the influence of changes in the initial projectile velocity, soil conditions, and impactor nose shapes. By means of X-ray radiography the vertical trajectory of the impactor has been recorded for analysis. These data have been used in the classical Poncelet penetration equations considering the force to be functionally related to a constant and velocity squared term. Further analysis, using the experimental data obtained, as applied to a multidegree of freedom rigid body model and a cavity expansion model are also discussed. As an integral part of the curren

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studies, the dynamic fracture of concrete bars has been examined in order to characterize the spall behavior of such specimens under dynamic loads. Finally, in order to examine the stress transmission characterization of various nose shaped penetrators, a series of dynamic loading tests using the Hopkinson Pressure Bar system have been reported on.

PREFACE

The work reported herein was performed under joint sponsorship by the Air Force Office of Scientific Research, Bolling AFB, D.C. 20332 and the Air Force Armament Laboratory, Eglin AFB, Florida 32542, under grant number AFOSR 77-3209. Mr. William J. Walker, AFOSR/NA, was the Air Force Program Manager.

The results described in this final scientific report summarize the technical effort accomplished in the period from December 1, 1976 through November 30, 1977.

The work was performed at the Engineering Science Department, University of Florida, Gainesville, Florida 32611, the University of Florida Graduate Engineering Center, Eglin AFB, Florida 32542, and the Laboratories of the Vulnerability Assessment Branch (DLYV) of the Air Force Armanment Laboratory, Eglin AFB, Florida 32542. University of Florida personnel who contributed to this study were R. L. Sierakowski, L. E. Malvern, J. E. Milton and C. A. Ross.

FOREWORD

It is known that wave propagation from an explosive source can create considerable damage at locations far removed from the detonation site. The extent of the resultant damage and types of failure occurring are dependent upon the medium through which the waves must travel as well as the strength, stand off distance, orientation, and type of device being used. For underground structures, the characterization of penetrator systems which can pass through various media and reach appropriate depth levels before detonating are important.

If proper placement of such detonation sources is made by external delivery systems, then a knowledge of the flight trajectory system through specific material overburdens is required and information on the structural integrity of the underground structures must be obtained. The problem is further complicated by the requirement that the structural integrity of the penetrator package must be ensured until the required depth of penetration is reached for proper detonation.

In order to design such systems, information on the path trajectories through material overburdens and properties of the materials penetrated as well as the penetrator must be determined. The studies reported on herein emphasize these specific subject areas. The results presented are based both upon experimental and analytical studies, and reflect investigations which encompass penetrator trajectories through various types of soil media, spall tests of specially prepared concrete samples, and the stress wave transmission through penetrators with varying nose shapes.

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SECTION I

STUDIES IN PENETRATION MECHANICS

1.1 INTRODUCTION AND BACKGROUND

The ability to deliver and detonate an explosive system is a complicated problem which requires knowledge for predicting the penetration of hardened materials. In order to develop a better understanding of the performance characteristics of kinetic energy projectiles penetrating through soil media a joint investigation has been conducted by the Vulnerability Assessment Branch (DLYV) of the Air Force Armament Laboratory with Mr. John Collins serving as project engineer and the University of Florida. The experimental facility for the penetration studies was located at Eglin Air Force Base with University of Florida personnel serving in a supportive and advisory capacity. Analysis of the data obtained was performed both at Eglin and at the University of Florida.

Previous studies concerning the mechanics of high speed earth penetrators, given the name terradynamic research, have been discussed rather comprehensively in reference [1]. While many models have been advanced since the 18th century for predicting path trajectories, depth of penetration, cavity formation, and vehicle stability, little supportive evidence in the way of experimental data has been available to reenforce or contradict these models. This has occurred in a large part because of the inherent difficulty of being able to visually record the transient penetrator passage through an opaque loose and/or semicohesive medium. These difficulties have been removed in the last few years through the use of multiple banks of X-rays stationed along the vehicle flight path as further described elsewhere in this report.

As a consequence of these results, the principal models

prepared in reference [1] can be examined. In general these predictive models can be categorized as being of the semi-analytical, analytical, theoretical and empirical type. For example, the first type which includes the classical Poncelet penetration model requires experimental data for evaluation of the penetration constants. The analytical models, such as the Cavity Expansion Model and Differential Force Law rely upon information concerning both penetration and the target material properties. The purely theoretical type models provide the ultimate in modelling procedures. These predictions are based upon continuum mechanics formulations describing both the penetrator and target and rely upon finite difference and finite element computer codes as solution techniques. A final empirical type of modelling procedure based purely upon collected experimental data has also been used for penetrator characterization.

The overall purpose of the current program has been to obtain basic data on projectile penetration into a soil medium and to study the physical mechanisms involved during penetration which might lead to better trajectory predictions for proposed terradynamic models, and better calculations of penetration depths and of the forces acting on the projectile. In addition to providing better physical insight for suitable terradynamic models, the test program has provided useful tabular data on several important parameters such as the force law coefficients necessary for analytical model representation. These results have been enhanced by the use of X-ray radiography to record the path trajectory and thus to visually observe the flight of the penetrator. In previous studies performed at Eglin and reported in reference [2], data for horizontal firings into dry and wet sand media were obtained for several different penetrator nose shapes. For the tests described in reference

[2], the firing velocity was controlled and limited to three different velocity regimes with penetrator impact at near zero degree obliquity. In the current test program penetrators of varying nose shapes, including many of these studied in reference [2], have been investigated for vertical firings over a wide range of firing velocities. These data have been used in both the classical Poncelet equations as well as in a three dimensional terradynamic predictive model developed as input within the scope of the current program. Further, the analytical cavity expansion model has been extended and compared with the experimental data obtained. Finally, field tests measuring the velocity of sound waves in soil are reported on for low frequency, high amplitude signals. These data are considered as potentially important for delineating bounds of applicability of certain force law models and as a parameter input into force laws containing velocity dependent terms.

1.2 EGLIN PENETRATION EXPERIMENTS - EQUIPMENT AND PROCEDURES

Penetration experiments were performed by firing projectiles vertically into sand targets contained in a specially designed test chamber. Most of the tests were performed with dry Eglin sand that had been sieved with a U.S.Standard Series No. 25 sieve to remove large debris, but not sieved to a controlled size range. Some tests were also made with saturated sand, and a few shots were fired into water. A total of 133 firings were made. Of these 111 produced sufficient data for analysis of the velocity by the methods of Section 1.4. The vertical firing program was an extension of a previous horizontal firing program of 91 shots at impact speeds in three ranges centered around 200, 300, and 400 m/s, as reported in reference [2].

Besides the change to vertical firing, which was made to see if gravitational effects would significantly change the results, the new program also included shots at lower impact

speeds to assess the velocity dependence of the force-law parameters of the data analysis. These two controlled laboratory investigations were designed to obtain more complete transient records of the penetration events than previous investigators had obtained in order to provide insight into the actual physical mechanisms involved, which could lead to better terradynamic penetration models for predicting trajectories, penetration depths, and the forces acting on the projectile. In the test program five to seven consecutively spaced X-ray units have been used to visually record the transient position of several penetrators. Nonspinning projectiles of stable configuration with various nose shapes have been tested in dry and saturated sand at various impact speeds with near zero impact obliquity. This is believed to be the most extensive use ever made of flash radiography in terradynamic research. In addition to the X-ray units, velocity coil sensors have been used as monitoring devices in conjunction with a magnetic tape recording system as reported in [2]. This supplementary monitoring was very useful for checking against the X-ray data. Since the sequential flash X-ray technique gave more complete and precise information about the projectile position and attitude, only the X-ray data will be presented and analyzed in this report.

The investigation used modelled 20 mm projectiles fabricated both at AFATL and at the University of Florida. These projectiles were cylinders 0.02 m in diameter by 0.15 to 0.38 m in length. The primary test program for the vertical firings [106 shots into dry sand] used flat-nose projectiles, which gave the most stable trajectories. Most of these were solid cylinders, but one series of 15 shots used a cylinder with part of the afterbody hollow. Smaller test programs were carried out with two nose shapes. Figure 1 is a photograph showing nine of the projectiles*. The two at the left will be referred to as

*Figures appear at the end of each section.

having Step-Tier noses, while the one at the right will be called a Step-Cone nose.

The projectiles were fired into the test chamber with a 20 mm gun placed in a vertical position on the roof of the laboratory with muzzle approximately three meters from the target. Firing velocity was varied by varying the powder load in a primed 20 mm case. After passing through a noncontacting vertical pipe into the laboratory, the projectile broke two paper back velocity screens of a Terminal Ballistics Data Acquisition System at nominal distances of 0.71 m and 0.10 m from the target to provide approach velocity information.

Figure 2 shows the gun in place on the roof of the laboratory.

In the vertical firing experiments the projectiles were fired into a test chamber consisting of a long box, some 2.25 m high with nominal lateral dimensions of 0.16 x 0.27 m. The side walls were made of aluminum sheets 0.0023 m thick and framed by steel brackets. The top end was closed by fiber board easily penetrated by the projectiles.

To monitor the projectile flight through the sand in the 2.25 meter long box, up to seven Hewlett-Packard flash X-ray units, two 150 KV soft X-ray units and five 300 KV hard X-ray units were used. A typical arrangement of the seven units had 150 KV units in positions No. 1 and No. 7 and the remaining 300 KV units in position No. 2 through No. 6, with the seven positions at distances of approximately 0.15, 0.42, 0.79, 1.14, 1.56, 1.98, and 2.12 m as measured from the top of the box. Figure 3 shows the X-ray film packs being placed on a metal frame hinged at the bottom so that it would bring the films into the proper positions when the frame was in a vertical position, and to bring them into a convenient position for unloading them when the frame was swung down after each shot.

The upper part of the test chamber is also shown in Figure 3 , with one of the 150 KV X-ray heads visible at the upper end of the test chamber (see arrow).

Figure 4 shows a view of the back end of the X-ray stand, with the housings of four of the 300 KV X-ray units visible. The X-ray firing sequence was triggered by a third velocity screen at the top of the box [not visible in the figure]. A series of metal letters (A through V were taped along the box, separated vertically by approximately 0.10 meters along a line from the top of the box, to serve as markers for locating the projectile position in the X-ray pictures.

For the dry sand tests the sand was poured slowly into the test chamber from a bucket assembly attached to an overhead crane. The wet sand tests were for the fully saturated condition. For the wet sand tests the sand was first mixed with water in a container and then shoveled into the test chamber. The sand was maintained in a fully saturated condition by adjusting a flow of water into the top of the box to compensate for leakage and maintain an essentially constant water level.

Standard triaxial tests were performed on two samples of the Eglin sand. For these tests the sand was first carefully dried following procedures as described in Reference [3]. Each sample was tested at three different constant values of the lateral confining pressure σ_3 (0.1962, 0.392, and 0.589 MPa) with axial compressive stress σ_1 increased until failure occurred (with failure defined as significant increase of axial strain at constant load). The two samples were a loose sand and one compacted by vibration before testing. Table I lists the initial density ρ_o and the angle of friction ϕ determined for each sample by analysis of the triaxial data as well as the value $(\sigma_1 - \sigma_3)_f$ of the stress difference at failure for each of the confining pressures.

TABLE I

TRIAXIAL DATA FOR DRY EGLIN SAND

	σ_3	$(\sigma_1-\sigma_3)_f$
Loose Sand	0.1962 MPa	0.538 MPa
ρ_o = 1519 kg/m^3	0.392	0.983
ϕ = 33.4°	0.589	1.447
Compacted Sand	0.1962	0.763
ρ_o = 1698 kg/m^3	0.392	1.423
ϕ = 39.7°	0.589	2.02

Similar triaxial tests were run on two samples of the dry sand after it had been used several times in the penetration experiments to see if the properties were significantly changed by the accumulation of fine dust particles produced in the impact. The results showed little change.

The curve of $\sigma_1 - \sigma_3$ versus axial strain ε_1 for the loose sand at the highest confining pressure was given in reference [2] where it was used to determine the deviatoric properties for the penetration analysis by the spherical cavity expansion theory method. Several confined uniaxial strain tests were also performed on dry Eglin sand [2].

The data collected in the vertical firing experiments will be described in Section 1.3.

1.3 RESULTS OF EGLIN PENETRATION EXPERIMENTS

1.3.1 Introduction

During the period from 9 November 1976 to 16 September 1977 penetration studies were conducted at Eglin AFB which included a total of 133 vertical firings over a period of 28 days. Appendix A lists data extracted from the X-ray pictures for 123 of the shots, and excludes 10 shots [these being 1, 14, 29, 36, 40, 45, 47, 100, 105, and 125] for which transient position and time data were obtainable at fewer than two of the

seven S-ray stations. Twelve other shots gave transient data for fewer than four stations [Shots 5, 35, 44, 59, 61, 63, 86, 95, 98, 108, 112, and 120]. For these no velocity analysis was performed. Thus in Appendix A there are 111 shots for which velocity analysis is given and 12 without velocity analysis.

1.3.2 Description of Tabulated Experimental Data

Table II shows an example [for Shot 43]of the kind of information listed in Appendix A for all shots independent of whether or not the velocity of the projectile was analyzed. In the caption the parentheses contain the date (day-month-year) and the sequenced shot number on that date. The next two lines list the target type (dry sand, wet sand, or water), the density in kg/m^3 of the projectile and the approach velocity in meters per second as recorded using the two velocity screens described in Section 1.2. This is followed by the projectile type, mass, and length.

TABLE II

SHOT 43 (13-04-77, NO. 1)

DRY SAND DENSITY = 1538 KG/M**3; APPROACH VELOCITY = 110. M/S
SOLID FLAT NOSE PROJECTILE: MASS=0.3661 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.7
TIME (SECONDS).....	0.00054	0.00193	0.00564	0.01056	*******
NOSE POSITION (M)..					
X-COMP.	0.15762	0.15547	0.16864	0.18113	0.22081
Y-COMP.	0.09051	0.33419	0.76729	1.11139	1.75551
TAIL POISITION (M).					
X-COMP.	*******	0.15135	0.16560	0.17080	*******
Y-COMP.	*******	0.18123	0.59738	0.95508	*******
YAW ANGLE (DEG)...	0.3	1.0	7.4	3.1	0.2
C.G. POSITION (M).					
X-COMP.	0.15682	0.15341	0.16712	0.17597	0.22041
Y-COMP.	0.01451	0.25771	0.68234	1.03324	1.67951

Next the seven X-ray stations are listed with the sequential times of firing listed in the following line. The next listings are for the coordinates of the centers of the projectile nose and tail as determined from the X-ray film [corrected for X-ray beam divergence] and the yaw angle in the plane of the film. [The columns for Stations 5 and 6 have been omitted in Table II.] Finally the calculated center of gravity coordinates are given in the last two lines of the table. In Appendix A these are followed by additional calculated information used for velocity analysis, as described in Section 1.4.

In Table II , a row of asterisks indicates that the data is missing. The time for Station 7 is always missing since the X-ray was always fired after the projectile had stopped in order to locate the final position of the penetrator. In Table II the tail position is also missing for Station I and in Appendix A all the position data are missing for Stations 5 and 6 of Shot43 .

The nose and tail coordinates listed in Table II and Appendix A were corrected for X-ray beam divergence using the following procedure. The raw data [not given in Appendix A] included the apparent nose and tail positions as actually measured on the X-ray film using an Information International Incorporated FR-480 Graphics Plotter at the Math laboratory of AFATL and the apparent projectile diameter. This apparent diameter when compared to the actual diameter provided a first-order correction for X-ray beam divergence. A simple computer program, based on similar triangles with apex at the X-ray source, was then used to correct all apparent horizontal and vertical distances in proportion to the known correction for the diameter.

For reference purposes, the y-coordinate was measured

positively down from the velocity screen used to trigger the X-ray firing sequence. This screen was placed at the top of the 12.5-mm-thick fiber board that closed the top of the test chamber. The x-coordinate was measured from one side of the box as it appeared on the X-ray film. This resulted in an x-coordinate of about 0.135 m for a direct hit and straight trajectory, although there was some variation between shots. The yaw angle was also measured from the downward y-axis toward the positive y-axis. Thus a positive yaw angle means that the nose x-coordinate is larger than the tail x-coordinate. The z-coordinate and pitch angles [in the yz-plane] were not measured. The z-direction is the direction of the minimum dimension of the test chamber [0.16 m].

From the positioning of the X-ray there was some overlapping of the X-ray beams in the film plane, so that one film usually contained information from more than one X-ray firing. Frequently the nose position for a given firing appeared on a different film from the one showing the tail for the same firing. The yaw angles as measured on the two films usually differed slightly. The yaw angles as listed in Table II and Appendix A represents the average of two such readings.

The calculated center of gravity position (c.g.) was based on the nose and tail positions when both were available. When either the nose or tail position was missing from the data, the center of gravity position was calculated from the end position that was available and the yaw angle as measured in the film showing the available end position. By using these procedures it was possible to locate transient center of gravity positions for at least four of the first six stations in 111 shots. For 55 shots it was possible to locate the transient center of gravity positions for all six stations.

1.3.3 Experimental Programs

The primary experimental program of 106 shots was concerned with flat-nosed projectiles impacting dry sand. Table III is the experimental matrix for this program. It lists the six projectile types in the first column. The first five solid projectiles are listed in order of increasing mass [and length]. The sixth had part of the afterbody hollowed so that the center of gravity was forward of the geometric center of the projectile. The next four columns of the table list the shot numbers for each projectile type in four velocity ranges. The velocity range categorization was initially based upon the measured approach velocity measurements are missing have been added to the table in the columns that seemed appropriate according to the data analysis described in Sec. 1.4 [Shots 48, 51, 52, 54, 55, 56, 58, 65, 66, 67, 68, 69, 70]. Five of the 106 shots of the primary test program [14, 29, 47, 100, 105] produced no transient position information and have been omitted from the matrix of Table III and from Appendix A. Nine more marked with an asterisk in Table III had fewer than four transient positions available for velocity analysis. The remaining 92 shots have been analyzed according to the classical one-dimensional terradynamic penetration models described in Sec. 1.4.

In addition to the primary test program involving flat-nosed projectiles impacting dry sand targets, a few shots were made with other types of projectiles and/or targets. Table IV lists II shots in dry sand with two different types of solid projectiles having step-tier noses.

TABLE III

PRIMARY TEST MATRIX - FLAT-NOSE PROJECTILES IN DRY SAND

PROJECTILE	SHOT NUMBERS IN FOUR VELOCITY RANGES			
MASS	50-150 M/S	150-250 M/S	250-350 m/s	above 350 m/s
0.367 kg	37,38,43 61*	50,51,60,52,54 44*	49, 62, 48 63*	64,65,72,73,76, 77,78,79,83,84, 85,87,88,89,102
0.497 kg	41,42	2,3,6,9,10,11 58, 5*	4	
0.545 kg	18,19,20,21,24 25,28,30,31,57	15,16,17,22,23 32,33,53,55,56,67	8,66,68,69 70,74	71,80,81,82
0.737 kg	113,121 98*,112*,120*	104,122,132 95*	131	91
0.920 kg	103	94,97,127	90	
HOLLOW 0.631 kg	101,111,119, 126, 108*	96,99,110,118	92,128,130	117,129

*Fewer than 4 stations

TABLE IV

SOLID STEP-TIER PROJECTILES IN DRY SAND

Mass	Shot Numbers in Three Velocity Ranges		
	50-150 m/s	150-250 m/s	250-350 m/s
0.372 kg	45,46	35*, 39	
0.515 kg	26,27		7,12,75,114,115

*Fewer than 4 stations

Seven solid Step-Cone nose projectiles were also fired into dry sand at approach velocities above 350 m/s, these being Shots 93, 106, 107, 109, 116, 123, and 124 in Appendix A.

Two other shots into saturated sand are tabulated in Appendix A, these being Shots 47 and 57 both for flat-nosed projectiles. The only shot with reducible data was for Shot 57.

Finally, there were three shots into water, Shots No. 59, 86, and 133, but Shot 133 had transient position information for four stations.

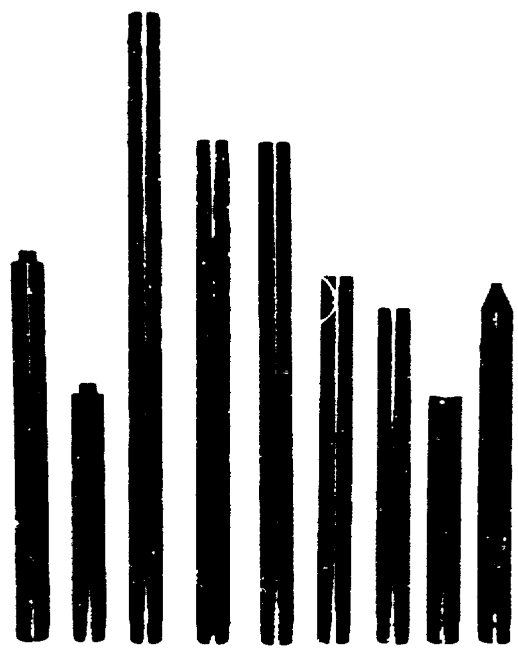


Figure 1 (above) Projectiles Used in Eglin Experimental Program

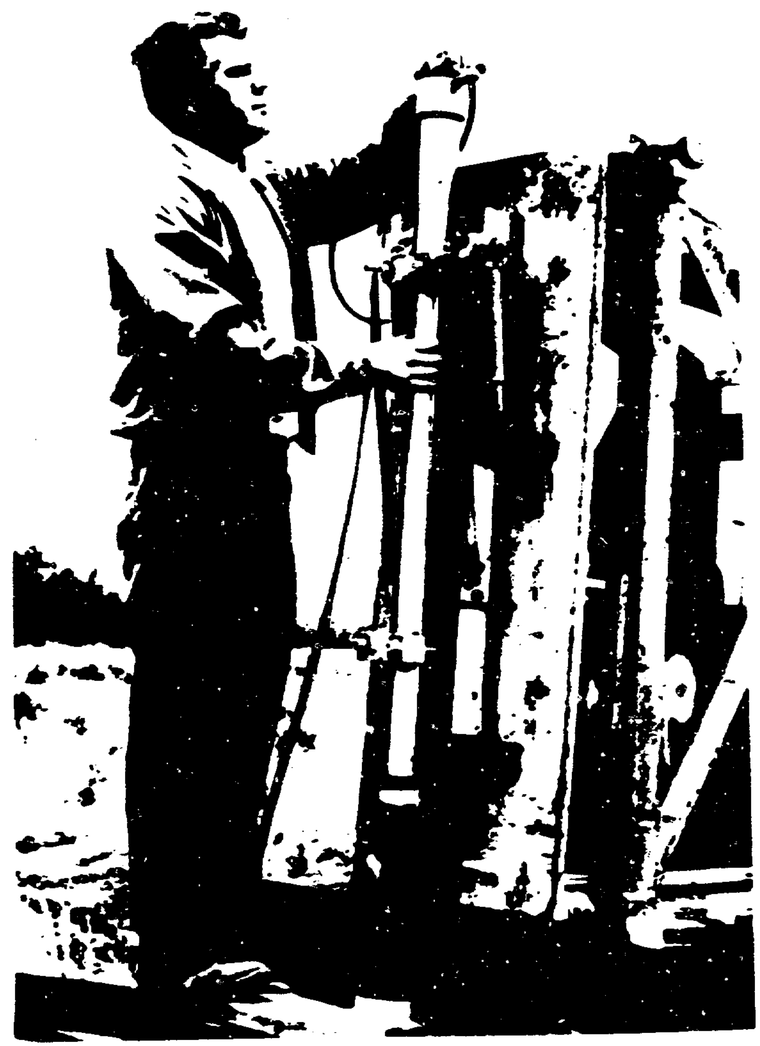


Figure 2 (at right) Roof-Mounted 20 mm Gun for Vertical Firing

Figure 3. X-Ray Film Pack
Installation in Test Facility

Figure 4 Rear View of X-Ray Stand

1.4 CLASSICAL ANALYSIS OF EXPERIMENTAL DATA

1.4.1 Analysis Procedures

The classical one-dimensional Poncelet force law [4] takes the following form, after dividing through by the mass m of the projectile,

$$-\frac{dV}{dt} = A + BV^2 \tag{1}$$

where A and B are parameters depending on the target material as well as on m. Equation (1) is integrated to give

$$y = y_o + \frac{1}{B}\ell n\{\cos(\sqrt{AB}\ (t-t_o)) + \sqrt{B/A}\ V_o \sin(\sqrt{AB}\ (t-t_o))\} \tag{2}$$

and

$$V = \{(\frac{A}{B} + V_o^2)\ e^{-2B(y-y_o)} - \frac{A}{B}\}^{1/2} \tag{3}$$

where for the vertical tests described in Section 1.3 y is the coordinate measured positively downward from the X-ray trigger at the top of the box and V = dy/dt. In the higher velocity ranges previous investigations [5] have indicated that the contribution of the constant term A may be negligible, and the experimental y, t - data can be matched by a law of the form

$$-\frac{dV}{dt} = BV^2 \tag{4}$$

which integrates to

$$y-y_o = \frac{1}{B}\ \ell n[1 + BV_o(t-t_o)] \tag{5}$$

or

$$V = V_o\ e^{-B(y-y_o)} \tag{6}$$

The single parameter B is then conveniently represented in terms of a dimensionless drag coefficient C_D defined as in aerodynamics so that the drag force on an object of projected

area A_1 on a plane perpendicualr to the velocity is given by

$$\text{Inertial Drag Force} = \rho A_1 C_D V^2/2 \qquad (7)$$

where ρ is the density of the medium being traversed. Compari- with Equation (4), neglecting A, shows

$$B = \rho A_1 C_D/2m \quad \text{or} \quad C_D = 2mB/\rho A_1 \qquad (8)$$

The projectile mass in kilograms and the target sand density in kg/m^3 are tabulated for each shot in Appendix A. This procedure with A = 0 was used with considerable success in fitting the dry sand data for the horizontal tests reported in 1976 [2]. In those tests the transient observations were over that part of the test chamber where the projectile velocity was usually greater than 100 m/s.

In the present vertical test program information was sought over the lower velocity ranges by using lower impact velocities and by using a longer test chamber to permit observations in the vicinity of the maximum penetration depth. The results of those shots for which transient position-time information was obtained at four or more X-ray stations were analyzed by determining a best fit for the parameters A and B of Eq.(2) by a nonlinear regression procedure that minimized the sum S of the squares of the differences between the experimental y coordinates and those calculated by Eq.(2). For comparison with the previous horizontal test observations the second procedure, with A = 0, was also applied to the data.

For those shots where transient y, t - data were available at six stations both procedures were separately applied to the data from Stations 1 to 4, from Stations 2 to 5, and from Stations 3 to 6 as well as from all stations 1 to 6 to see if there was any consistent variation in the parameters obtained

as the projectile slowed down.

Because the approach velocity measurements were not believed to be as reliable as the X-ray position-time measurements, the approach velocity was not used for the value V_o. Instead a cubic interpolation formula was fitted by a linear regression method to the y, t-data, and the velocity calculated at one of the observation times by differentiating the cubic. This velocity, position, and time were then used for V_o, y_o, and t_o in Equation (2) or Equation (5). When data from five or six stations were being fitted, the third station available was used for V_o. When only four stations were used, the second station was used for V_o.

After V_o had been determined from the cubic fit, the parameters A and B [or B only for the second procedure with Eq.(5)] were determined by the Marquardt nonlinear regression procedure,references [6,7]. Some details about the regression procedure are given in Appendix B.

Table V gives an example, Shot No. 55, of the calculated results given in Appendix A. The fifth data group labeled C. G. POSITION (M) gives the center-of-gravity position coordinates as calculated from the preceding data [corrected for X-ray beam divergence] as described in Section 1.3. The next group gives the coefficients of the cubic interpolation polynomial fitted to the y , t-data. Thus for Shot 55 the cubic polynomial

$$y = -0.1005 + 188.6t - 6654t^2 + 93540t^3 \qquad (9)$$

gives y in meters for t in seconds.

The next group in Table V gives some calculated results based on the two-parameter Poncelet equation fitted to all six stations. The first line gives the calculated y-coordinate in meters of the center of gravity at each of the six X-ray sta-

Table V SHOT 55 (10-05-77 .NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5414 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS)......	0.00063	0.00252	0.00553	0.00943	0.01547	0.03208	*******
NOSE POSITION (M)..							
X-COMP.	0.17596	-.00953	0.17939	0.19757	0.21742	*******	*******
Y-COMP.	0.11793	0.46370	0.86943	1.26906	1.68533	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.17246	-.01681	0.15967	0.17909	0.24485	0.23931
Y-COMP.	*******	0.23621	0.64637	1.03664	1.46668	2.07870	2.12777
YAW ANGLE (DEG)....	-0.6	0.3	1.8	5.7	7.7	-1.1	-1.6
C.G. POSITION (M)..							
X-COMP.	0.17851	0.08147	0.08129	0.17862	0.19826	0.24053	0.23323
Y-COMP.	0.00546	0.34996	0.75790	1.15285	1.57601	2.19112	2.24011

COEF. OF CUBIC POLYNOMIAL: -0.1005D 00 0.1886D 03 -0.6654D 04 0.9354D 05

FROM PONC. Y C.G. =	-0.01751	0.32948	0.75790	1.17004	1.61668	2.18618	********
ERROR (M).......	0.02297	0.02048	0.0	0.01719	0.04067	-0.00493	********
C.G. VY (M/S) =	204.	164.	124.	91.	60.	14.	

AT T=0.0. C.G. VY= 222. ; WHEN VY=0.0. T= 0.03885 AND Y= 2.23278

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A=	0.0	B=	0.7710	ER=0.00293	EM= 0.0038	CD= 1.7278
STATIONS 2-5	A=	0.0	B=	0.7162	ER=0.01154	EM=-0.0156	CD= 1.6049
STATIONS 3-6	A=	0.0	B=	0.7599	ER=0.06759	EM=-0.0735	CD= 1.7029
ALL STATIONS	A=	0.0	B=	0.9064	ER=0.07224	EM=-0.1267	CD= 2.0313
STATIONS 1-4	A=	2261.0	B=	0.6435	ER=0.00371	EM= 0.0053	
STATIONS 2-5	A=	2261.0	B=	0.5315	ER=0.00388	EM=-0.0049	
STATIONS 3-6	A=	2261.0	B=	0.4081	ER=0.01843	EM=-0.0221	
ALL STATIONS	A=	2261.0	B=	0.5230	ER=0.02541	EM= 0.0464	
STATIONS 1-4	A=	1443.5	B=	0.6875	ER=0.00307	EM= 0.0049	
STATIONS 2-5	A=	3035.1	B=	0.4720	ER=0.00242	EM=-0.0028	
STATIONS 3-6	A=	2306.1	B=	0.4018	ER=0.01839	EM=-0.0218	
ALL STATIONS	A=	1997.0	B=	0.5680	ER=0.02417	EM= 0.0407	

tion firing times. The second line of this group gives the error at each station, i.e. the difference between the calculated Y C.G. according to the Poncelet formula and the experimental value from the fifth data group. For Shot 55 the maxierror according to the Poncelet formula is about 4 cm at Station 5.

The third line of this data group lists the calculated y-component of the center of gravity velocity [VY = dy/dt] at each of the six X-ray firing times. When the calculation predicts VY = 0 before the experimental firing time of the sixth X-ray, the equation would give a negative VY for Station 6. Such meaningless negative values have been omitted from Appendix A, for example for Shots 22 and 23.

The last line of this data group lists first the calculated VY when T = 0, that is when the velocity screen at the impact point started the timing counters. This is included for comparison with the recorded approach velocity. Since at this time the projectile has not started embedment in the sand, the backward extrapolation to T = 0 would be expected to overestimate the approach velocity somewhat. The approach velocity in most cases is probably somewhere between this value and the calculated value for Station 1. Many discrepancies are found in the recorded approach velocity (see, for example, Shot 2 in Appendix A). For Shot 55 and several other shots the approach velocity record is missing. The last two entries on the fourth line of this data group give the calculated T in seconds and Y in meters when the calculated VY becomes zero. This calculated Y should be comparable to the experimental C.G. Y-COMP recorded at Station 7.

The last set of entries in Table V lists the fitted Poncelet coefficients and two error measures for each of the fitting procedures used. For Shot 55 three different proce-

dures were used, and the results are tabulated in three groups of four lines each. The first four-line group with A = 0 based on Eq.(5), lists the fitted B, the error measures ER and EM, and the drag coefficient CD, for fitting to Stations 1-4, 2-5, 3-6 and to all six stations. The second group also uses a fixed A but for a nonzero constant value, the choice of which will be explained later. The last four-line group gives the A and B values determined by the two-parameter nonlinear regression. As would be expected, this two-parameter regression procedure gives a better fit to the six station data than either of the one-parameter regression procedures, as indicated by the smallness of the error measure ER.

The error measure ER is the RMS error in meters, $ER = [(\text{Calculated } Y - \text{Experimental } y)^2/N]^{1/2}$, where N is the number of stations used in the fit (not counting the station used for V_o, where the error is zero) while EM is the maximum error at any of the stations used. For example, in the last line of Table V, ER = 0.02417 is the RMS average of the five errors previously tabulated along with the calculated results based on the two-parameter Poncelet equation, while EM = +0.0407.

The second procedure, with a nonzero constant A was tried as an attempt to reduce the scatter in the values of A and B given by the regression procedure. From a physical point of view A is the limiting value of the deceleration as the velocity V approaches zero. At high velocities it turns out that BV^2 dominates in Equation (1) so that the calculated y versus t is not very sensitive to the choice of A, and the regression procedure sometimes gives erratic values of A, which which tend to increase the scatter in the values of B. Since A is more important at low speeds, the regression gives more consistent values for A at low speeds. The value A = 2136 m/s^2

used in the second procedure was obtained as the average value found for A at low speeds for nine shots into dry sand with the type of projectile used in Shot 55, as discussed in the following section. This second procedure, with A = 2136 m/s^2, was then used only for the analysis of the 30 shots into dry sand with this projectile type for which transient data were available from at least four stations, including 20 shots with transient data from six stations.

1.4.2 Results of Analysis

As is indicated by the primary experimental matrix, Table III of Sec. 1.3, the most complete data were obtained for the solid flat-nose projectiles of nominal mass 0.545 kg and length 0.225 m impacting dry sand. The results of this group have therefore been chosen for discussion in this section. We consider first the two-parameter Poncelet equation fit based on transient data from six stations. This complete data is available for 20 shots. The resulting values of A and B are summarized in Table VI in two groups; 12 shots for which the calculated V_1 at Station 1 was less than 250 m/s and 8 shots with $V_1 > 250$ m/s. The average value of B in the low-velocity group was essentially equal to the average for all the shots, but the average of A for all shots was about 1.5 times that for the low velocity group, indicating that A may depend on velocity, so that the assumption of a resisting force equal to $m(A + BV^2)$ with constant A and B leaves something to be desired. There was also more scatter in the values of A fitted to different shots than in the values of B.

The question of the apparent variation of A and B with velocity during a single shot trajectory was also examined by separately fitting the experimental data for Stations 1-4, 2-5, and 3-6 for the same 20 shots considered for all six stations in Table VI. While it was easy to make a good fit to

TABLE VI

PONCELET PARAMETERS FOR 20 SHOTS IN DRY SAND WITH FLAT-ENDED SOLID 0.545 kg PROJECTILE

V_1<250 m/s						V_1>250 m/s		
Shot	B (m^{-1})	A (m/s^2)	Shot	B (m^{-1})	A (m/s^2)	Shot	B (m^{-1})	A (m/s^2)
19	0.645	1754	28	0.634	1340	8	0.681	2929
20	0.504	2243	31	0.610	1715	66	0.750	1564
21	0.631	1315	53	0.616	1998	68	0.571	3851
22	0.452	3597	55	0.568	1998	69	0.579	3544
23	0.468	3670	56	0.646	1469	70	0.515	5252
24	0.632	1501	67	0.675	1445	71	0.564	4601
12 SHOTS V<250 m/s AVERAGE B=0.590 m^{-1} AVERAGE A=2004 m/s^2						74	0.547	7456
						82	0.540	6525
ALL 20 SHOTS AVERAGE B=0.591 m^{-1} AVERAGE A=2988 m/s^2								

Stations 1-4 and to Stations 2-5, as indicated by the error measures ER and EM the fit to Stations 3-6 was typically less good, often giving errors as large as those of the fit to all six stations. This may be caused by the long time interval between Stations 5 and 6. The values of A and B obtained were also more scattered than the values obtained using six stations, complicating the assessment of velocity dependence of A and B. To reduce the confusion of the plot, the values obtained in various velocity ranges were averaged. Thus in Figure 5 the first value plotted for B is $B = 0.39\ m^{-1}$, the average of 9 values of B fitted to Stations 1-4 for 9 shots in which the average $\bar{V}$ of the four values of V calculated at Stations 1-4 fell in the interval from 60 m/s to 80 m/s. The error bars indicate the largest and smallest of the 9 values used. Three shots in this velocity range [Shots 20, 22, and 23 were excluded from the averaging because the values of B were considered completely unrealistic.] Similar averages and error bars are shown for A and B in each of the 20 m/s - wide intervals from 60 m/s up to 200 m/s. The last point plotted on the right is for $\bar{V}$ between 200 m/s and 250 m/s.

The 8 $\bar{B}$ values plotted are joined by solid line segments, while the $\bar{A}$ values are joined by dashed line segments. Examination of the $\bar{B}$ plot suggests that there are two velocity regimes. Below about 80 to 90 m/s is a low-velocity regime with $\bar{B} = 0.39\ m^{-1}$. The average of B for 44 cases with $\bar{V} > 80$ m/s is $\bar{B} = 0.578\ m^{-1}$ with a standard deviation of $0.145\ m^{-1}$. In this higher velocity regime it seems reasonable to say that B is substantially independent of velocity, and the average obtained from all the 4-station subgroups in the high-velocity regime does not differ much from the average [$\bar{B} = 0.591\ m^{-1}$] listed in Table VI for the 6-station fitting. The plot of the $\bar{A}$ values in Fig. 5 is not so easily characterized.

There is much wider scatter of the A values, as indicated by the error bars, and the trend is not clearly evident. If the last point is ignored, there seems to be something of an upward trend of A with increasing velocity instead of separation into two regimes. The last point shown is an average of only three values, and moreover at the higher velocities A has only a small effect on the total deceleration.

For comparison with the previous analyses of horizontal test firings, reference [2], the one-parameter Poncelet equation with A = 0 was also fitted to the experimental data. Also a fitting to the data for the projectile type of Table VI and Figure 5 in dry sand was made by fixing A = 2261 m/s^2, the average of the 9 values of A fitted to the first four station data for the low velocity regime 60-80 m/s, which was most sensitive to variations in A, that is the first point on the A plot of Figure 5. It was hoped that this would reduce the scatter in the B values at higher velocities. Figure 6 compares the variations in $\bar{B}$ with velocity from the 4-station fittings for the three procedures: with A = 0 (triangles), with A = 2261 m/s^2 (squares), and the previous plot for B from Figure 5 repeated for comparison. The error bars have been omitted, but the scatter in B was actually worse with A = 2261 m/s^2 instead of better.

With fixed A = 2261 m/s^2, the $\bar{B}$ plot again separates into the same two velocity regimes as before. In the low velocity regime the average value was $\bar{B}$ = 0.374 m^{-1} for 12 values. In the high-velocity regime it was $\bar{B}$ = 0.614 with a standard deviation of 0.085 m^{-1}. The results with A = 0 did not separate into two regimes, but appeared to be substantially constant with $\bar{B}$ = 0.754 m^{-1} for 60 values, with a standard deviation of 0.095 m^{-1}, approximately equal to the value $\bar{B}$ = 0.769 m^{-1} [for 12 values with a standard deviation of 0.067 m^{-1}]

plotted for the velocity range below 80 m/s. The 4-station fittings with A = 0 gave consistent values of B, but did not give a good fit to the experimental values for Stations 3-6, the low velocity region. For example, in Table V for Shot 55, the maximum errors in meters based on Stations 3-6 are, EM = 0.0735, -0.0221, and 0.0218, respectively, for the fittings with A = 0, A = 2261 m/s^2, and A determined by the fit. The poor fit with A = 0 in the low velocity region is not surprising, since the constant A is more important there. For these comparisons the average velocity used for each 4 station group was always the arithmetic mean of the 4 values calculated by the two-parameter Poncelet 6-station fit. For comparison with the previous results for horizontal shots into dry sand, reference [2], four-station groups with the first station velocities within 5 per cent of the initial velocities of the horizontal firings of the same projectile type were selected, as summarized in Table VII.

TABLE VII COMPARISON OF DRAG COEFFICIENTS FOR HORIZONTAL AND VERTICAL SHOTS IN DRY SAND

SOLID FLAT-NOSED PROJECTILES WITH MASS 0.545 kg, LENGTH 0.225 m							
Velocity Range 200-220 m/s				Velocity Range 305-336 m/s			
Vertical		Horizontal		Vertical		Horizontal	
Shot	C_D	Shot*	C_D	Shot	C_D	Shot*	C_D
23	1.662	17*	1.64	70	1.605	20*	1.77
55	1.728	18*	1.62	71	1.710	23*	1.72
56	1.796	19*	1.69	82	1.516	24*	1.72
67	1.698						
Averages							
	1.72		1.65		1.61		1.74

*Shot No. from Ref. [2]

From this comparison no consistent difference emerges between the vertical and horizontal shot test results. The average for the vertical tests was a little higher at low velocities and a little lower at high velocities than for the horizontal tests. These particular shots were chosen because their velocities so closely matched those of the horizontal shots. The average $\bar{B} = 0.754$ for all 60 4-station values with $A = 0$ gives $\bar{C}_D = 1.71$ for the vertical shots, very nearly equal to the average 1.695 for the six horizontal tests listed.

It may be noted that with $A = 0$, the six-station values fitted for B and therefore for C_D were always larger than the values for any of the 4-station groups. For example, Table V lists CD = 2.0313 based on all six stations and CD = 1.7029 based on Stations 3-6. With A = 0 the six-station average value for 20 shots was $\bar{B} = 0.929\ m^{-1}$ with a standard deviation of $0.076\ m^{-1}$. This would give $\bar{C}_D = 2.09$ based on the six-station fits with A = 0.

The six-station fits with A = 0 were generally quite poor as indicated by the root-mean-square error ER and maximum error EM tabulated for each fitting in Appendix A. Figures 7, 8 and 9 show plots of y versus t and V_y versus t for Shots 22, 55 and 68, each fitted by all three procedures.

Experimental y-t points for six stations are marked by circles. The horizontal line at the upper right in each figure is at the final post-shot position of the projectile. All three fitting methods give close agreement with each other and with the experimental points in the range covered by the experimental points. Divergence occurs for extrapolated values at the beginning and especially at the end. The calculated V_y-t curves diverge more than the y-t curves, as would be expected. The y-t curves fitted by the three methods are represented by a single curve over a considerable range of t,

since the calculated differences there were so small that it was difficult to show them in the plots. These three curves are typical of the quality of fitting to the experimental y-t six-station data. The fitting quality based on only four or five stations was, however, often not this good, as is indicated by the error measures ER and EM tabulated in Appendix A.

In Figures 7 and 8 for Shots 22 and 55 the calculated y-t curve for the two-parameter fitting (solid curve) agrees closely with the post-shot rest position, while for Shot 68 it does not. For Shots 22 and 55 the experimental value at Station 6 was close to the final position, while for Shot 68 it was not so close and the calculated final position represents an extension of the fitted Poncelet curve farther outside of the range of experimental values to which it was fitted. For this case the close agreement of the final position calculated with $A=2261\ m/s^2$ is believed to be fortuitous. As expected, the curves with A=0 are completely unrealistic near the end, where V_y should reach zero. They also gave unreasonably high values of V_y at t=0.

The two-parameter model gives a closer fit to the experimental data than either of the other two, as would be expected, but all three fit the data well except at the ends.

The real test of a model is of course not its ability to be fitted to each individual shot, but its ability to predict the individual shots with material parameters otherwise determined. As some indication of how this might work for the group of shots that have been discussed in this section, final depth predictions were made, as follows. According to Eq. (3) of Section 1.4-2, V should drop to zero at $y=y_7$ given by

$$y_7 = y_1 + \frac{1}{B} \ln \left[1 + \frac{B}{A} V_1^2\right] \tag{10}$$

if the experimental value of y_1 and the tabulated calculated velocity at Section 1 are taken as initial conditions. This was done with the value of A chosen as $A=2004\ m/s^2$, the

average of the 12 A values from the low velocity six-station data of Table VI and with B=0.591 m^{-1}, the average of the values found for the six-station data. The results are tabulated in Table VIII for nine shots in the low velocity group for which final positions were known from the experimental data.

TABLE VIII - DEPTH PREDICTIONS WITH
$A=2004\ m/s^2$ $B=0.591\ m^{-1}$

Shot	V_1 (m/s)	Calculated y_7 (m)	Experimental y_7 (m)	Error (per cent)
19	172	1.906	2.042	- 7
20	170	1.888	2.260	-16
21	169	1.875	2.263	-17
22	197	2.134	1.958	+ 9
23	201	2.161	1.920	+12
24	188	2.054	2.239	- 8
31	186	2.038	2.148	- 5
53	188	2.092	2.152	- 3
55	204	2.176	2.240	- 3
67	210	2.147	2.273	- 6

In only three of the nine tabulated shots did the depth prediction error exceed 10 percent for these laboratory shots under controlled conditions. Greater errors would of course be found in field conditions with sand of variable and unknown properties.

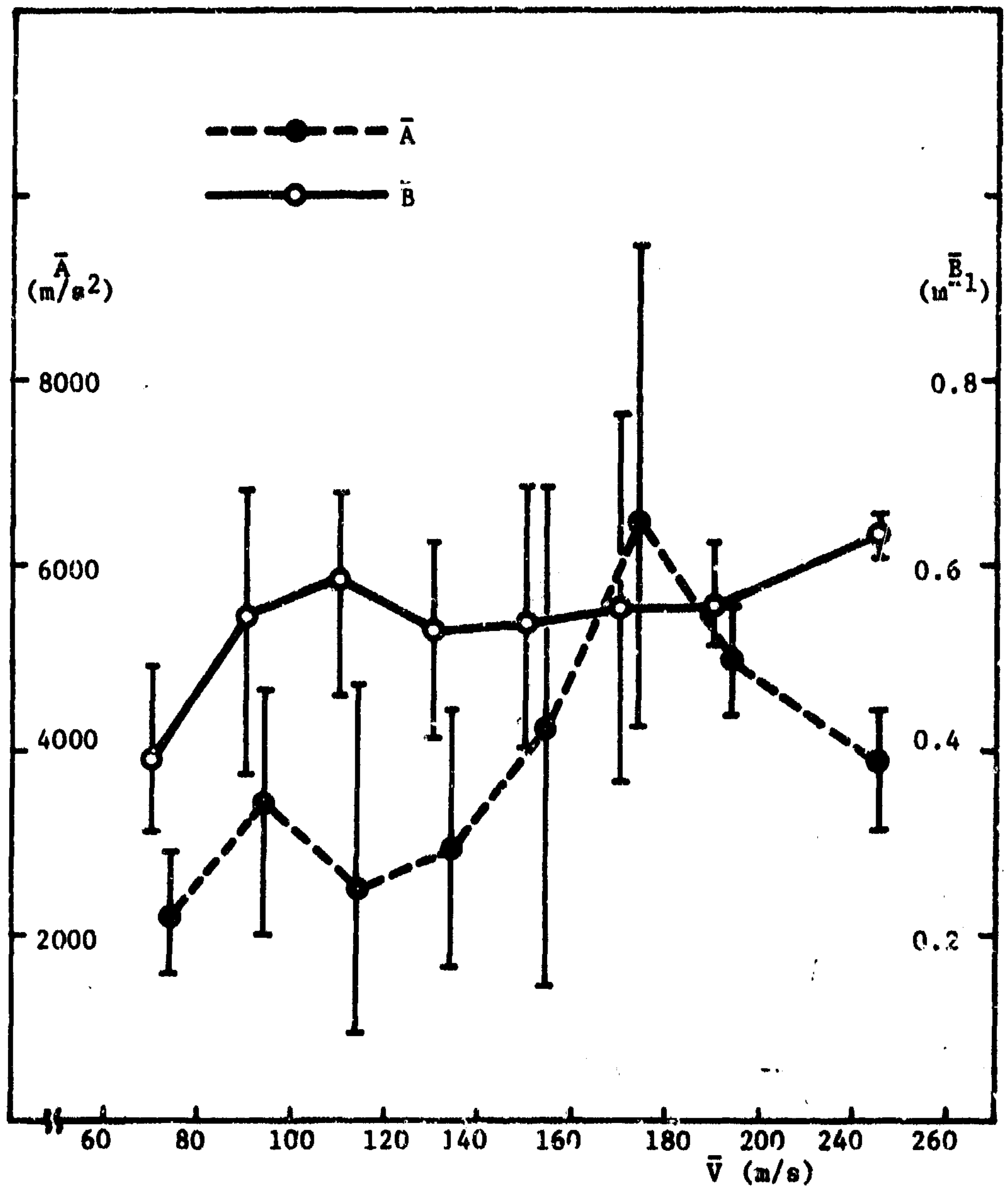


Figure 5. Variations of Average Poncelet Parameters $\bar{A}$ and $\bar{B}$ with Average Velocity $\bar{V}$ from Four-Station Fittings to Parts of Trajectories of 20 Shots.

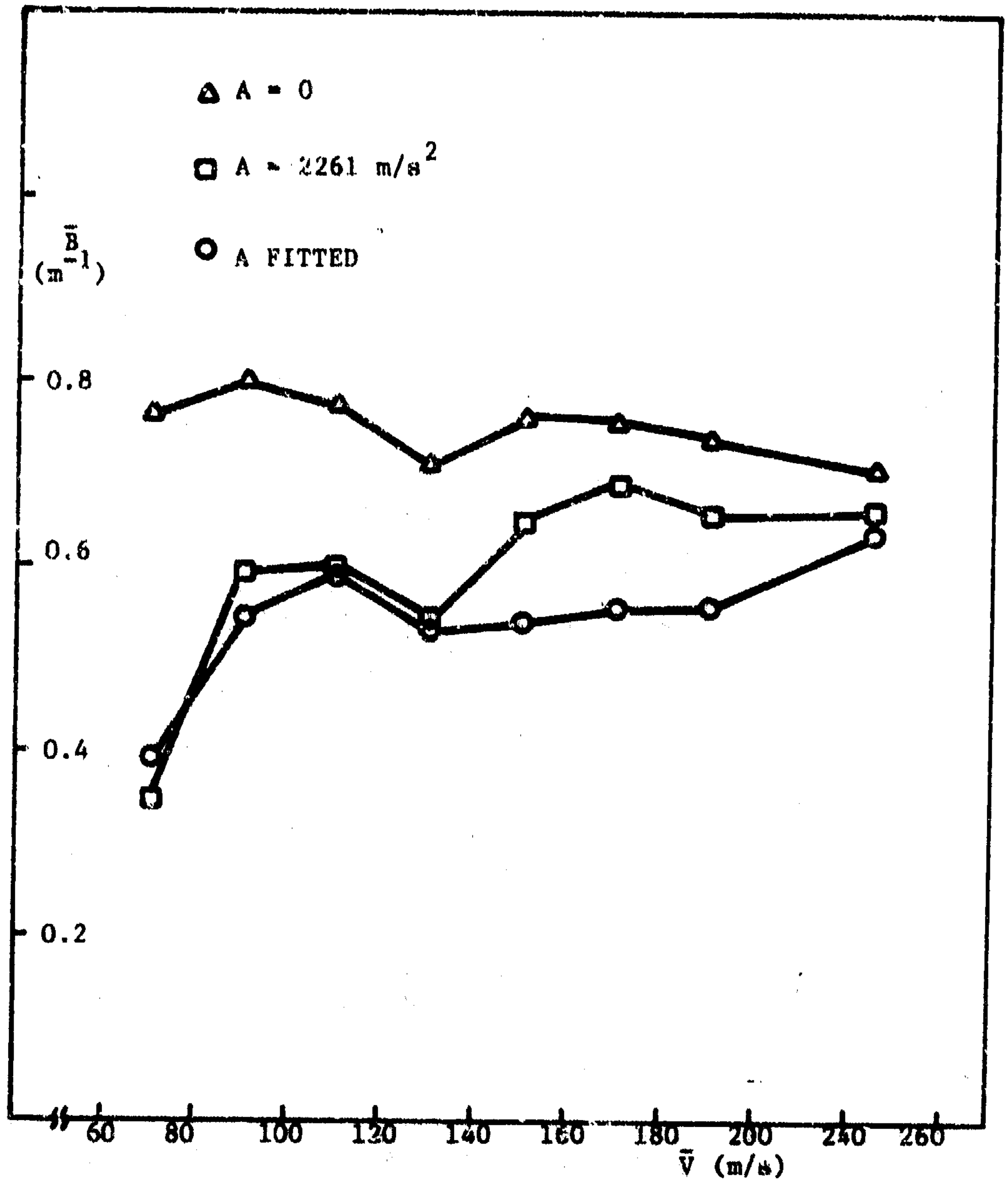


Figure 6. Comparison of $\bar{B}$ Variations with $\bar{V}$ in 20 Shots for $A = 0$ (triangles), $A = 2261\ m/s^2$ (squares), and A Fitted (circles).

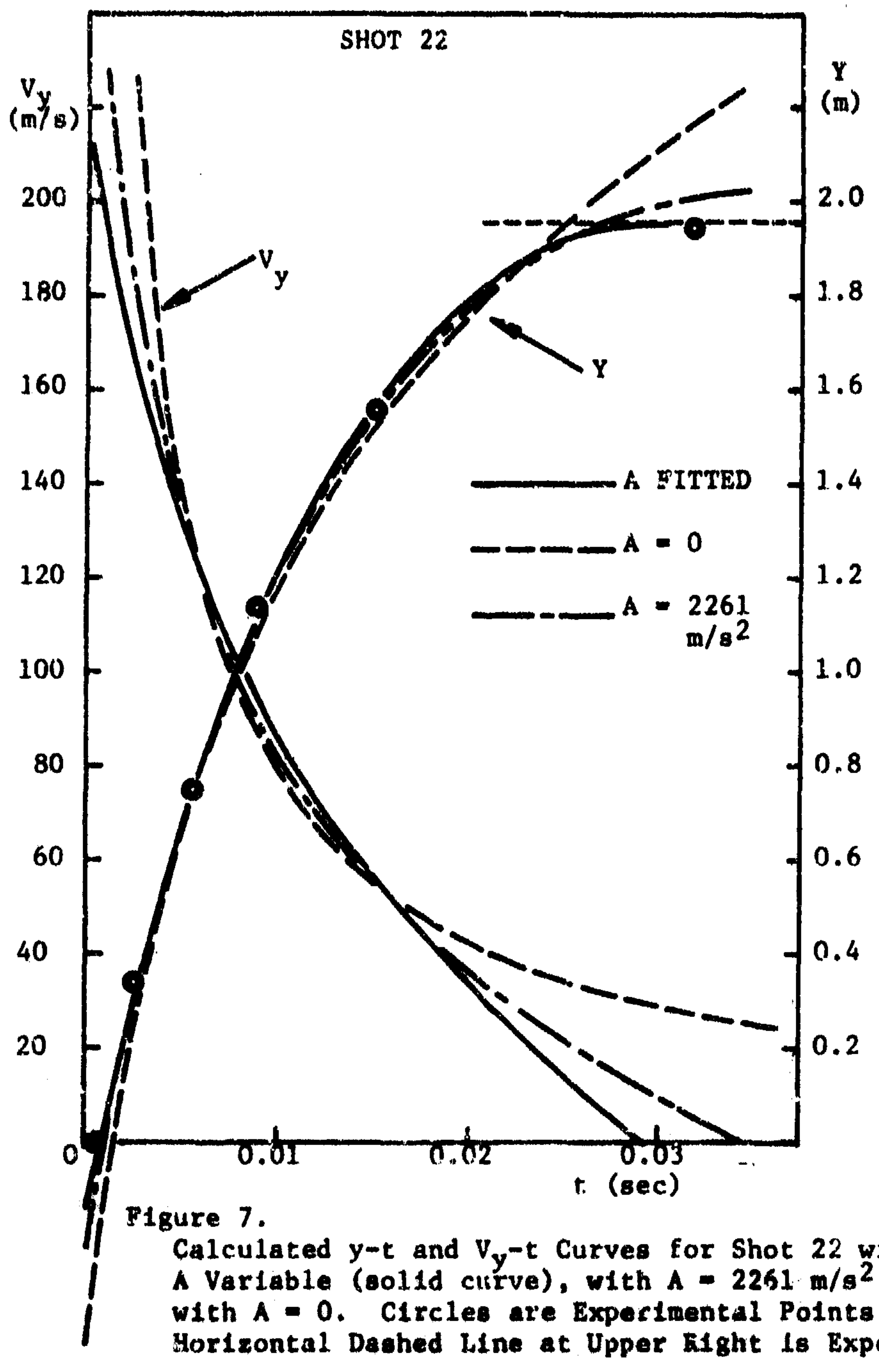


Figure 7.
Calculated y-t and V_y-t Curves for Shot 22 with A Variable (solid curve), with A = 2261 m/s^2, and with A = 0. Circles are Experimental Points. Horizontal Dashed Line at Upper Right is Experimental Final Position.

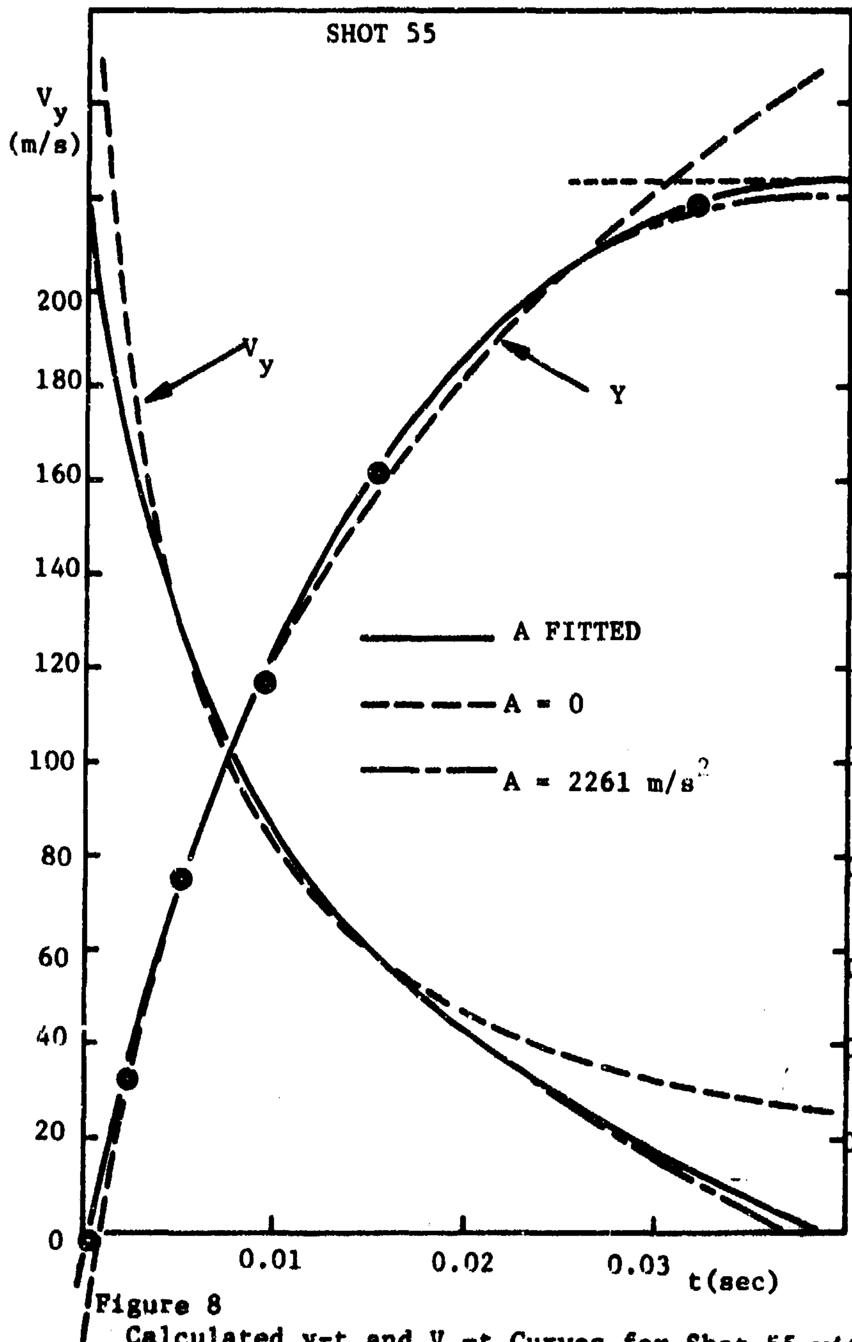


Figure 8
Calculated y-t and V_y-t Curves for Shot 55 with A Variable (solid curve) with A = 2261 m/s^2, and with A = 0. Circles are Experimental Points. Horizontal Dashed Line at Upper Right is Experimental Final Position.

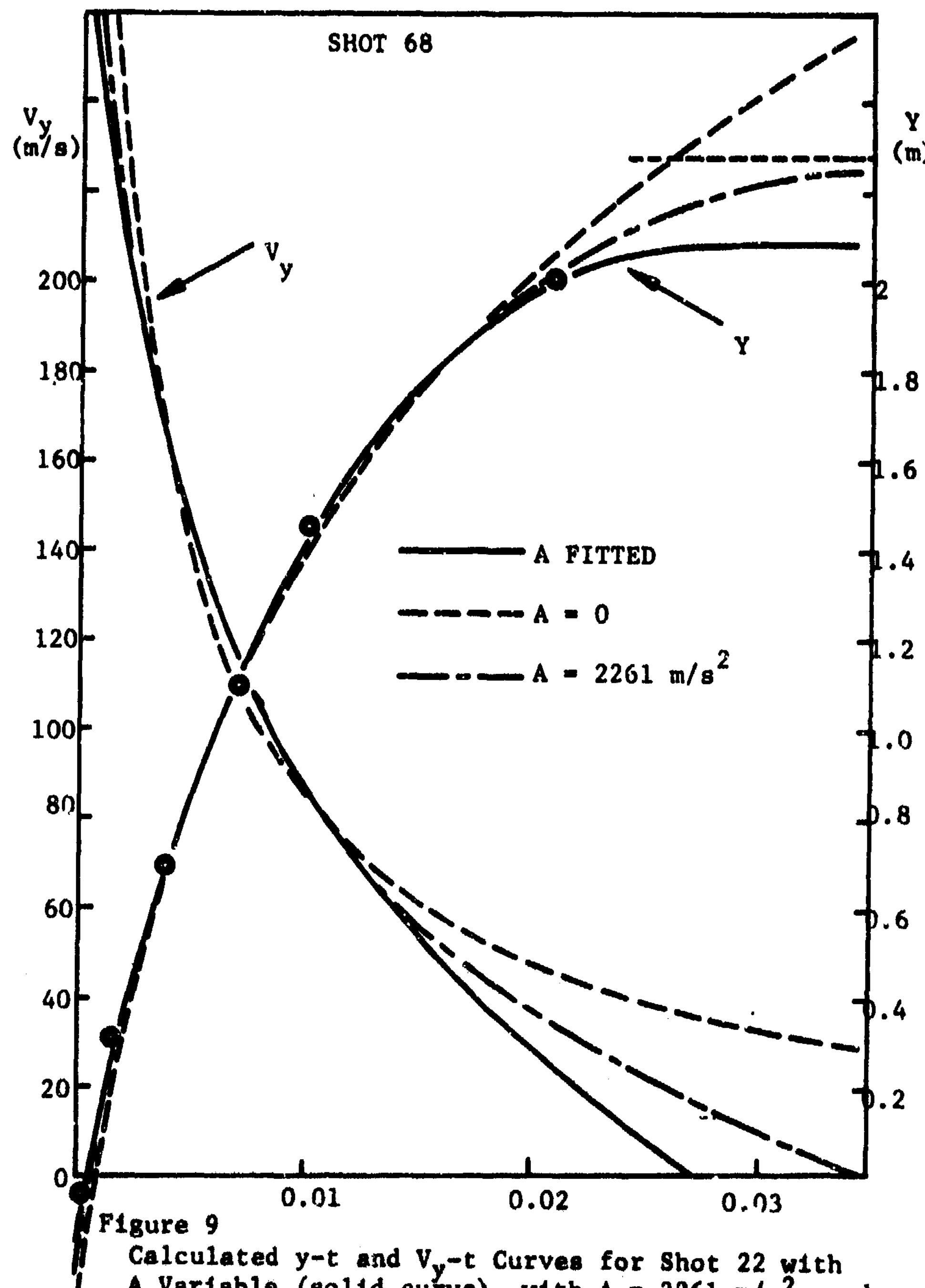


Figure 9
Calculated y-t and V_y-t Curves for Shot 22 with A Variable (solid curve), with A = 2261 m/s^2, and with A = 0. Circles are Experimental Points. Horizontal Dashed Line at Upper Right is Experimental Final Position.

1.5 DEVELOPMENT OF THREE DIMENSIONAL CODE

1.5.1 Introduction

Prior to the initiation of the work reported in this document the development of a three dimensional code for predicting the trajectory of a terradynamic vehicle was started, see reference [2]. The work reported here is a continuation of that effort and a detailed derivation of the equations involved will not be given here. The code was to be quite general so that it could be used for a wide variety of vehicles and soils. It was to be easy to use and require a minimum of computational time, and was to allow for theoretical, empirical or semi-empirical forcing functions.

1.5.2 Equations to be Solved

The equations of motion for a rigid body written with respect to a set of body fixed axes (x,y,z) whose origin is at the center of mass of the projectile are given in reference [8] as follows:

$$F_x = m(\dot{U}+QW-RV) \tag{11}$$

$$F_y = m(\dot{V}+RU-PW) \tag{12}$$

$$F_z = m(\dot{W}+PV-QU) \tag{13}$$

$$L = I_{xx}\dot{P}+I_{xy}(PR-\dot{Q})-I_{xz}(\dot{R}+PQ)+RQ(I_{zz}-I_{yy})+I_{yz}(R^2-Q^2) \tag{14}$$

$$M = I_{xy}(\dot{P}+RQ)+I_{yy}\dot{Q}+I_{yz}(PQ-\dot{R})+RP(I_{xx}-I_{zz})+I_{xz}(P^2-R^2) \tag{15}$$

$$N = I_{xz}(QR-\dot{P})-I_{yz}(\dot{Q}+PR)+I_{zz}\dot{R}+I_{xy}(Q^2-P^2)+QP(I_{yy}-I_{xx}) . \tag{16}$$

Where F_x, F_y and F_z are applied forces and U, V and W are velocities of the projectile along the x,y,z axes respectively. L, M

and N are applied moments and P, Q and R are projectile rotational velocities resolved along the x,y,z axes respectively. The projectile mass is represented by m and I_{xx}, I_{yy}, I_{zz}, I_{xy}, I_{xz} and I_{yz} are moments of inertia of the body referred to these body axes. See Figure 10 for sign conventions and Figure 11 for projectile nomenclature.

Once the applied forces and moments are determined these equations can be solved simultaneously in this coordinate representation. In order to transform the results into information that is meaningful to a fixed observer the Euler angle transformations are used. The order of rotations and angular designations are those of reference [8]. They are:

1. Start with body axis x, aligned with inertial axis x' and rotate about body axis z, through an azimuthal angle Ψ. This produces a new set of body axes X_2, Y_2, Z_2.
2. Rotate about Y_2 through a pitch angle θ. This produces a new set of body axes X_3, Y_3, Z_3.
3. Finally, rotate about X_3 through a roll angle ϕ, which brings the body into its final body axis system, x,y,z. (This rotation is not important for a body possessing complete symmetry about the x axis.)

The application of this transformation gives the Euler angle rates

and the translational velocity components in the inertial axis system x', y', z'. The equations are as follows:

$$\dot{\theta} = Q \cos \Phi - R \sin \Phi \tag{17}$$

$$\dot{\Phi} = P + Q \sin \Phi \tan \theta + R \cos \Phi \tan \theta \tag{18}$$

$$\dot{\Psi} = (Q \sin \Phi + R \cos \Phi) \sec \theta \tag{19}$$

$$U' = \frac{dx'}{dt} = U \cos \theta \cos \Psi + V(\sin \Phi \sin \theta \cos \Psi - \cos \Phi \sin \Psi)$$
$$+ W(\cos \Phi \sin \theta \cos \Psi + \sin \Phi \sin \Psi) \tag{20}$$

$$V' = \frac{dy'}{dt} = U \cos \theta \sin \Psi + V(\sin \Phi \sin \theta \sin \Psi + \cos \Phi \cos \Psi)$$
$$+ W(\cos \Phi \sin \theta \sin \Psi - \sin \Phi \cos \Psi) \tag{21}$$

$$W' = \frac{dz'}{dt} = - U \sin \theta + V \sin \Phi \cos \theta + W \cos \Phi \cos \theta \ . \tag{22}$$

Where U', V' and W' are velocity components along the inertial axis system x', y', z'. The coordinate systems are shown in Figure 10.

These twelve coupled differential equations have been programmed on the CDC 6600 computer at the Armament Development and Test Center (ADTC) at Eglin Air Force Base. They are solved by a fourth order Runga-Kutta technique.

1.5.3 Forcing Functions

The force exerted by the soil on the projectile can be modelled in various ways and two methods will be used in this work. The first started with the assumption that the force exerted by the soil on an elemental area of the surface of the body would be

$$\frac{d\bar{F}}{dA} = n_x(A_x + B_x|U| + C_xU^2)\hat{i} + n_y(A_y + B_y|V| + C_yV^2)\hat{j} + n_z(A_z + B_z|W| + C_zW^2)\hat{k} \quad (23)$$

where $d\bar{F} = dF_x\hat{i} + dF_y\hat{j} + dF_z\hat{k}$ and $\hat{i}$, $\hat{j}$ and $\hat{k}$ are the unit vectors in the body axis system, see Figure 10, and n_x, n_y, n_z are components of an outward directed unit vector normal to the projectile surface. The A's, B's, and C's are force coefficients to be determined from test performed for a certain projectile shape and a given soil. If the coefficients are known, the total forces can be obtained by integrating equation 23 over the watted surface of the projectile. By multiplying the force on one of the area elements by the appropriate lever arm an expression for the applied moments can be obtained. See Figure 12. These equations have been written for a conical nose and are given in reference [2]. The equations were derived with the assumption that the soil was in contact with the nose and was separated from the afterbody. This assumption is consistent with the Eglin X-ray data given in previous sections and also in reference [2]. The integration was performed by a Gauss-Legendre technique, see reference [9], and is included in the Eglin program.

The second method for obtaining the forcing functions was to use a pressure distribution over the nose of the projectile from the cavity expansion theory and integrate it over the nose surface.

These integrals yield a set of forcing functions which are also available as an option in the computer program. This option and some results obtained with it are discussed in Section 1.6.

1.5.4 Application of the Program

In order to establish the initial conditions for the calculation of a trajectory the point of contact of the nose with the target material is taken to be the origin of the x', y', z' coordinate system. The x' coordinate is taken normal to the target surface, and pointing inward. The mutually orthogonal y' and z' axes will lie in the plane of the target surface and can be oriented in any convenient direction. For example in the vertical shots the orientation taken was as shown in Figure 13. The value of x' gives the depth to which the center of mass of the projectile has penetrated. At the instant that the nose contacts the target surface the values of Ψ_o and θ_o along with the geometry of the projectile allows a determination of x_o', y_o', z_o'. The values of these angles and a knowledge of U_o', V_o' and W_o' allows a determination of U_o, V_o and W_o. The value of ϕ_o can always be taken to be zero if the projectile has rotational symmetry about the body axis, x. All of the projectiles tested did have this symmetry and $\phi_o = 0$ was always used. It is also necessary to know the initial values of the angular velocity rates, P_o, Q_o, R_o.

These initial values (U_o, V_o, W_o, x_o', y_o', z_o', P_o, Q_o, R_o, Ψ_o, θ_o and ϕ_o) constitute the initial values necessary for the numerical solution of the twelve coupled differential equations.

It has been found in previous work, reference [2], that even for a flat nosed projectile a soil nose or false nose will be formed which in the Eglin sand approximates a cone with a length to diameter ratio equal .4. The calculations for the normal incident shots shown in the next section were made assuming the existence of this false nose.

1.5.5 Results

The results of the Eglin test program for normal impact are presented in Appendix A. The force coefficients are given in two forms, a single coefficient C_D and two coefficients A and B. The coefficients, A, B and C_D are described in Section 1.4. From reference [2] the relationship between C_x, see equation 23, in the computer program and C_D is

$$C_x = \frac{\rho_s}{2}C_D \tag{24}$$

where ρ_s is the soil density. In the C_D model the other two coefficients A_x and B_x are zero. Figures 14, 16, 18 and 22 show the experimental results and the computer prediction using this C_D.

The A and B Coefficients in the data are converted to the coefficients for the program by

$$A_x = \frac{mA}{\pi r^2} \tag{25}$$

and

$$C_x = \frac{mB}{\pi r^2} \tag{26}$$

where r is the radius of the vehicle. In this model the B_x is equal to zero. Figures 15, 17, 19, 20, 21 and 23 show the results of the computer predictions using the A and B coefficients.

Figures 20 and 21 are given to demonstrate some of the other plots available in the program. In practically all cases the A_x, C_x model predicted the time versus velocity and the velocity versus the depth of penetration better than the C_D model.

Figures 24 and 25 show a calculation based on the expanding cavity pressure distribution that is described in Section 1.6. The data are from reference [2].

As can be seen from the figures, the agreement between the computer prediction and the data for normal impact is quite good for the C_D, A and B and the expanding cavity models. In general, shots where the velocity was monitored below about 50 meters/second were predicted more accurately by the A, B model than the C_D model. The lack of data and force coefficients for the y and z directions has prevented a full blown six-degree of freedom calculation at the present time, although a three-degree of freedom calculation shown in Section 1.6 shows reasonable agreement.

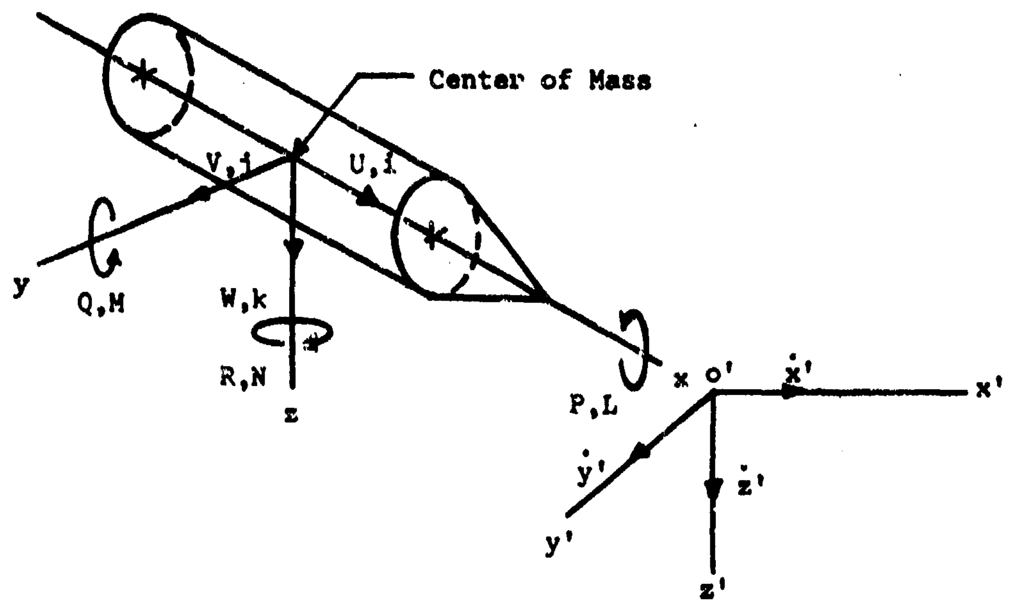


Figure 10. Schematic of Body and Inertial Axes.

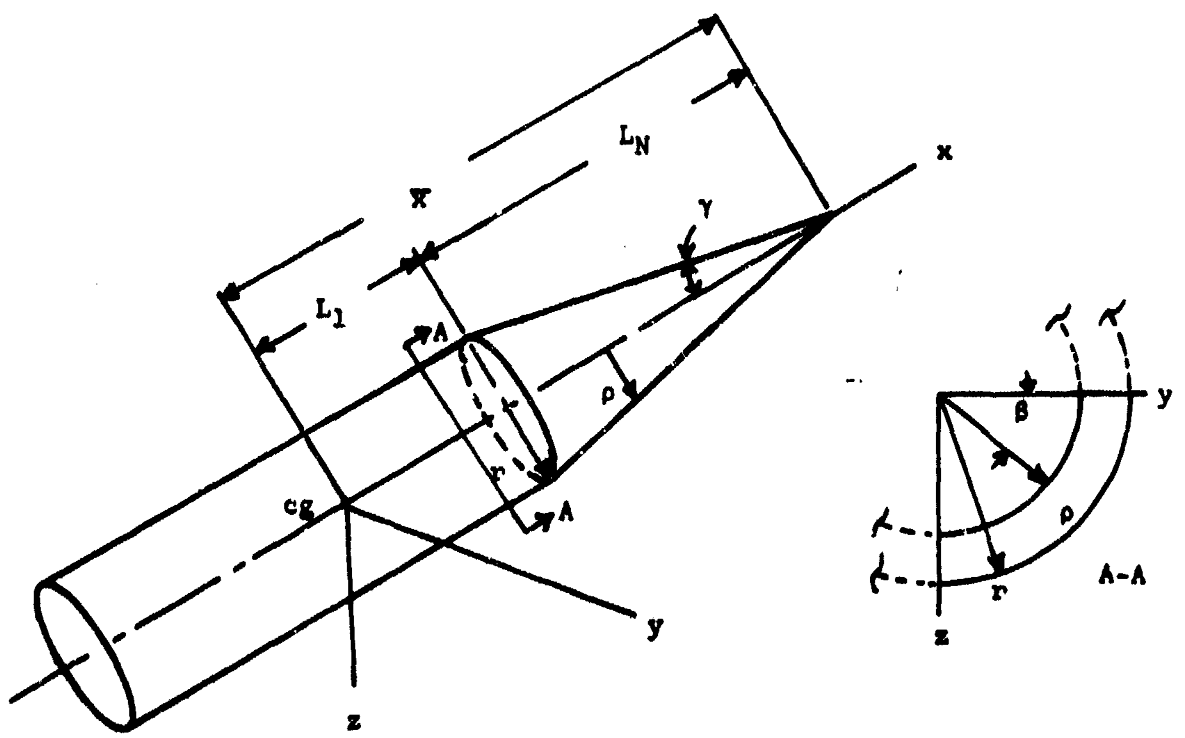


Figure 11. Projectile No iature and Coordinates.

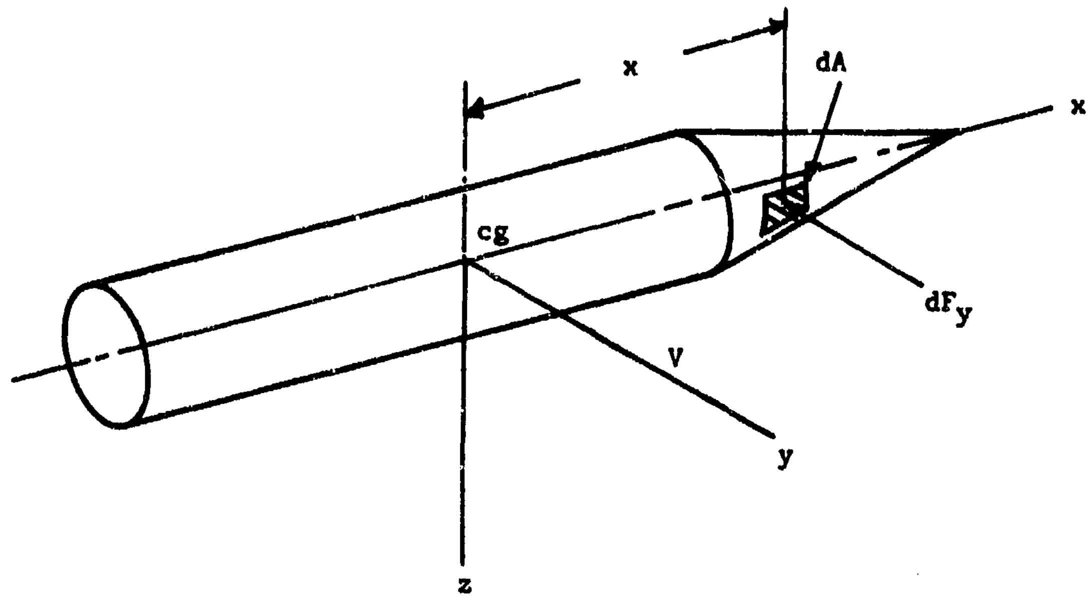


Figure 12. Schematic Showing Differential Force dF_y.

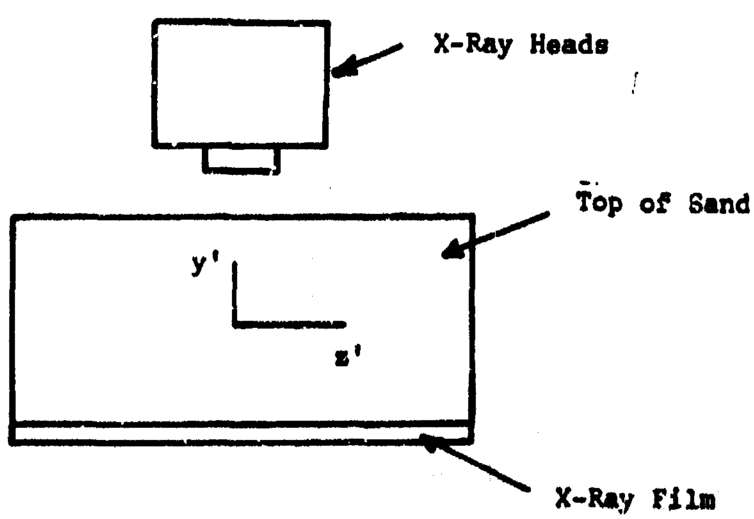


Figure 13. Inertial Coordinate System. x' Points Downward into the Sand.

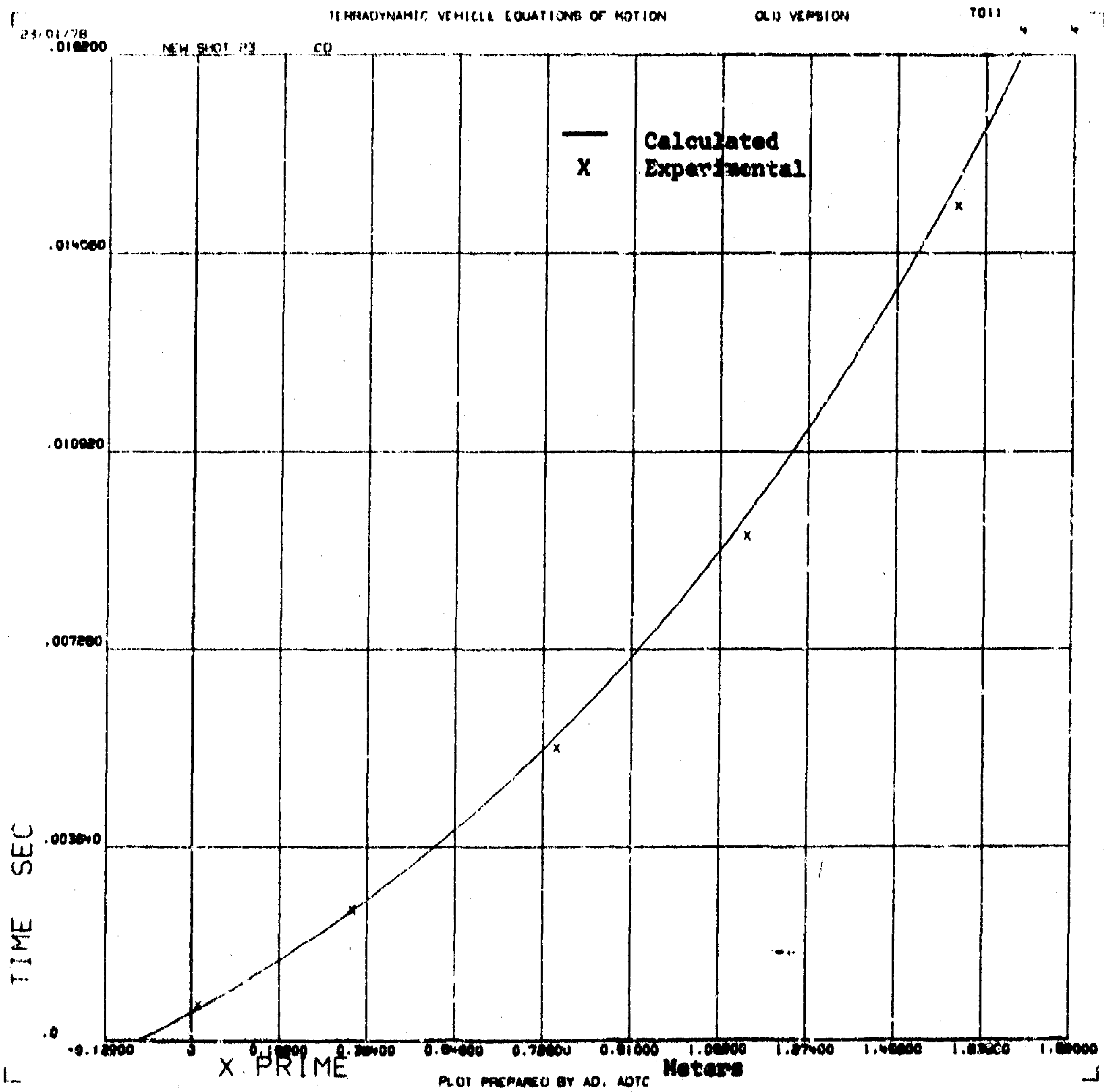


Figure 14. Time Versus Depth of Penetration for Shot No. 23. (C_D Model)

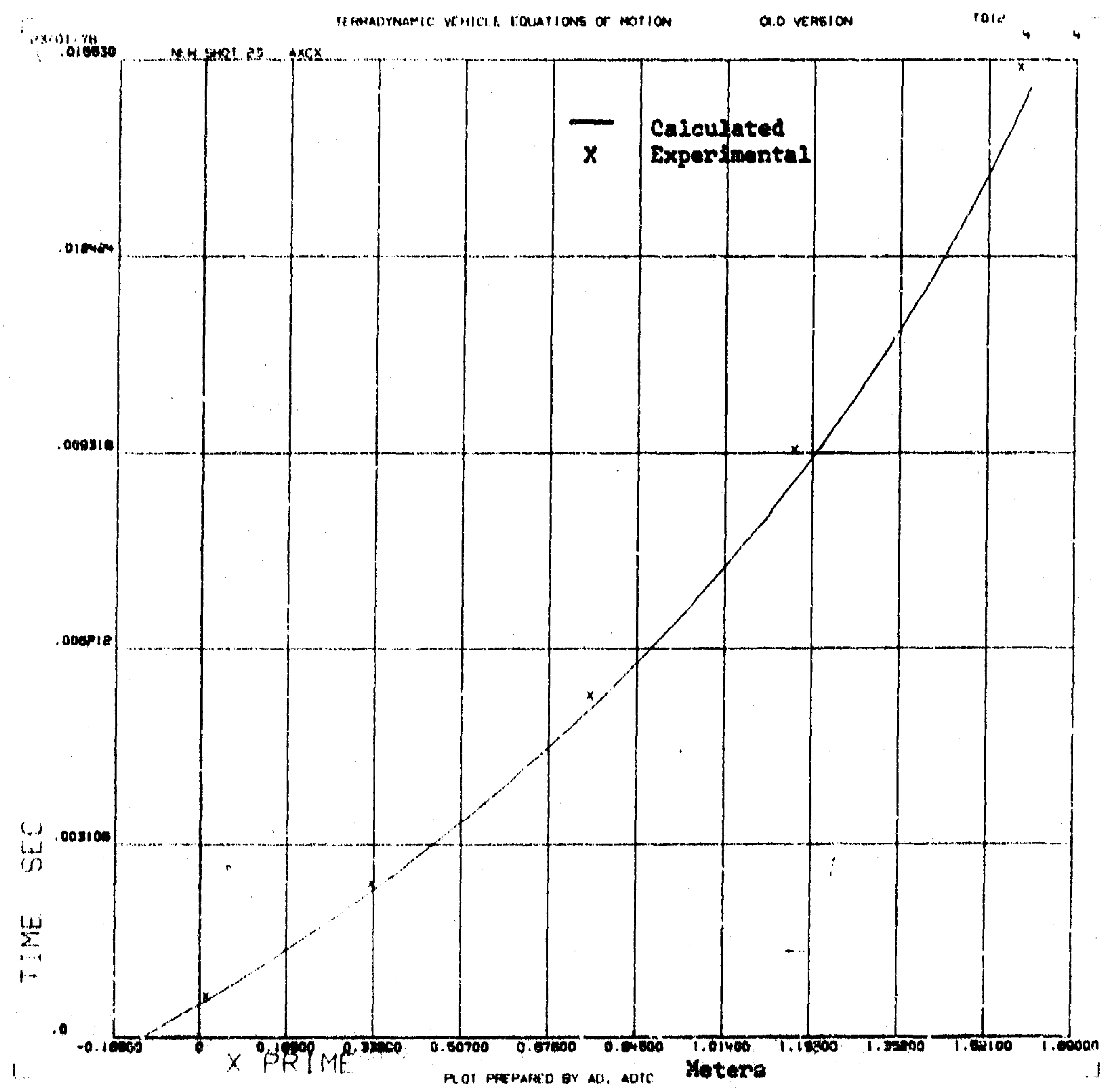


Figure 15. Time Versus Depth of Penetration for Shot No. 23. (A_X,C_X Model)

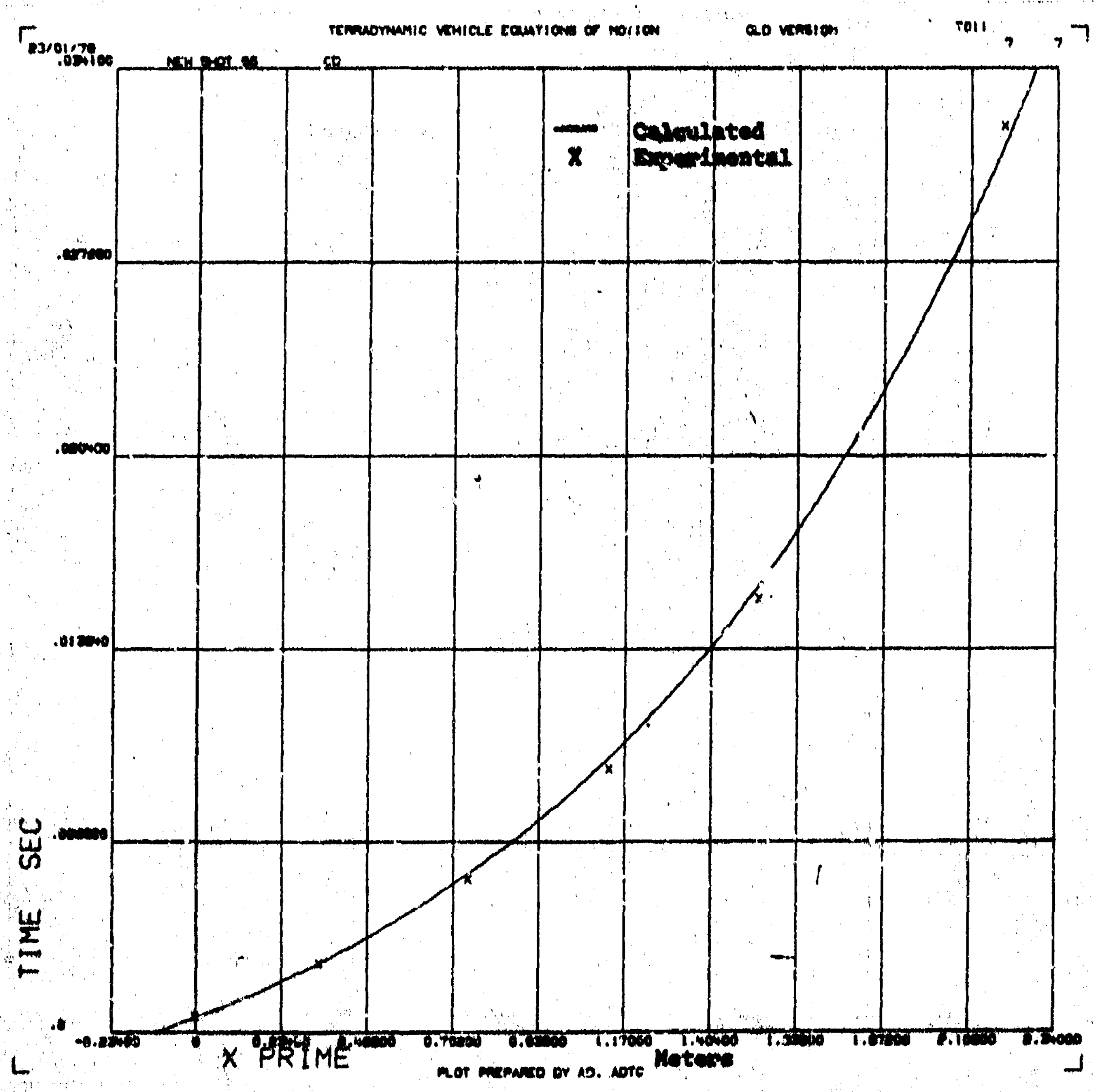


Figure 16. Time Versus Depth of Penetration for Shot No. 56. (C_D Model)

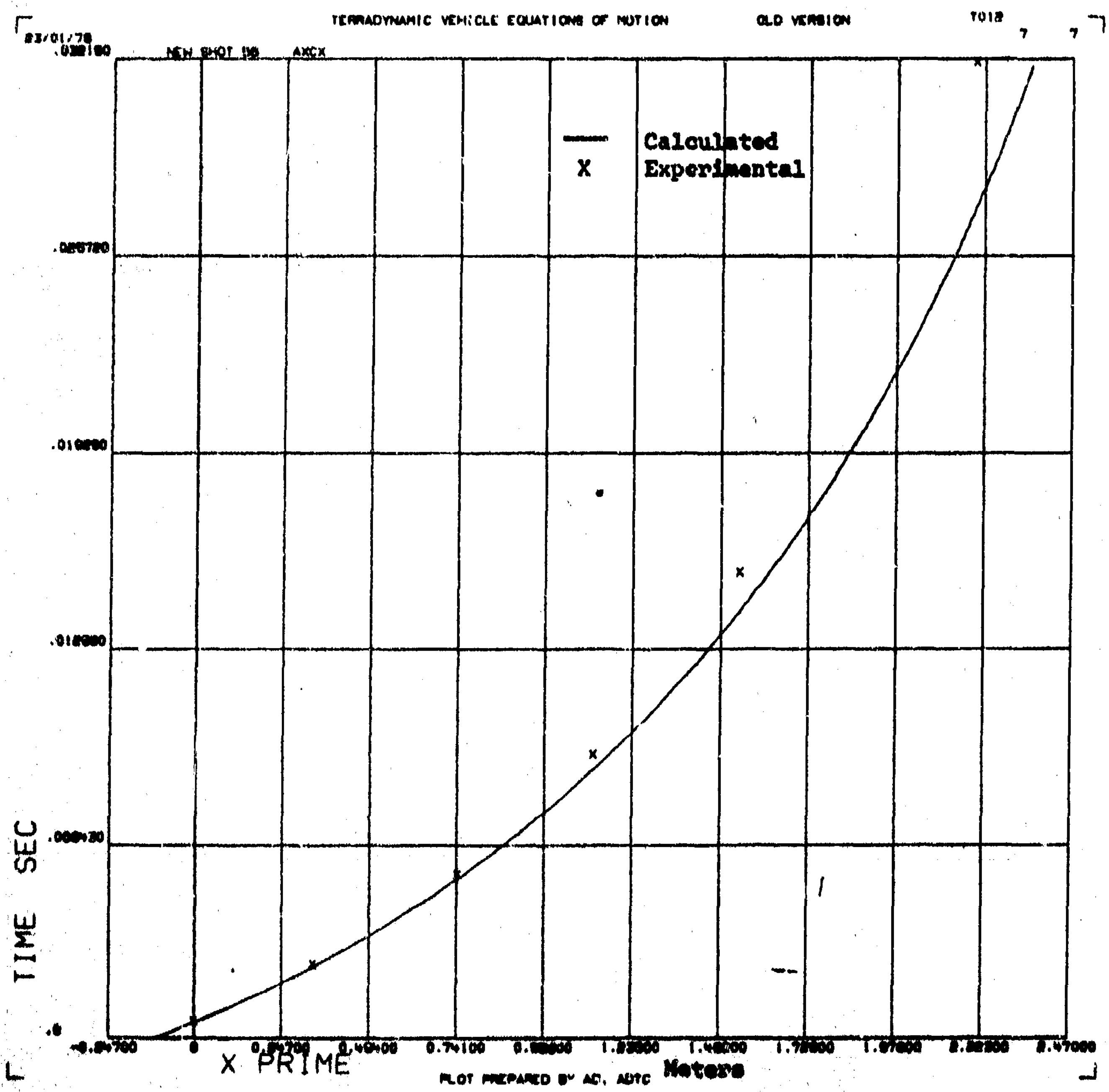


Figure 17. Time Versus Depth of Penetration for Shot No. 56. ($A_X C_X$ Model)

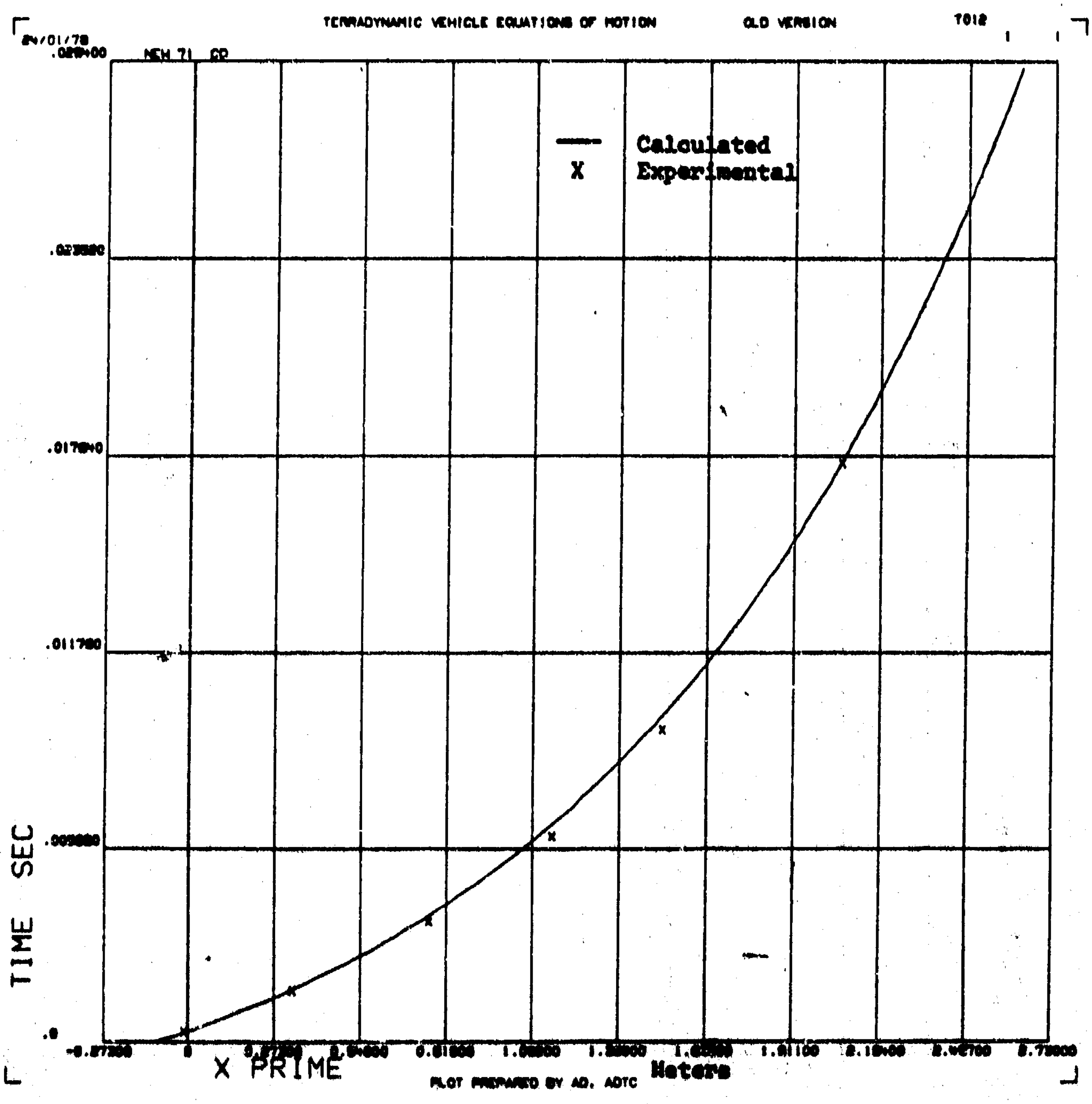


Figure 18. Time Versus Depth of Penetration for Shot No. 71.
(C_D Model)

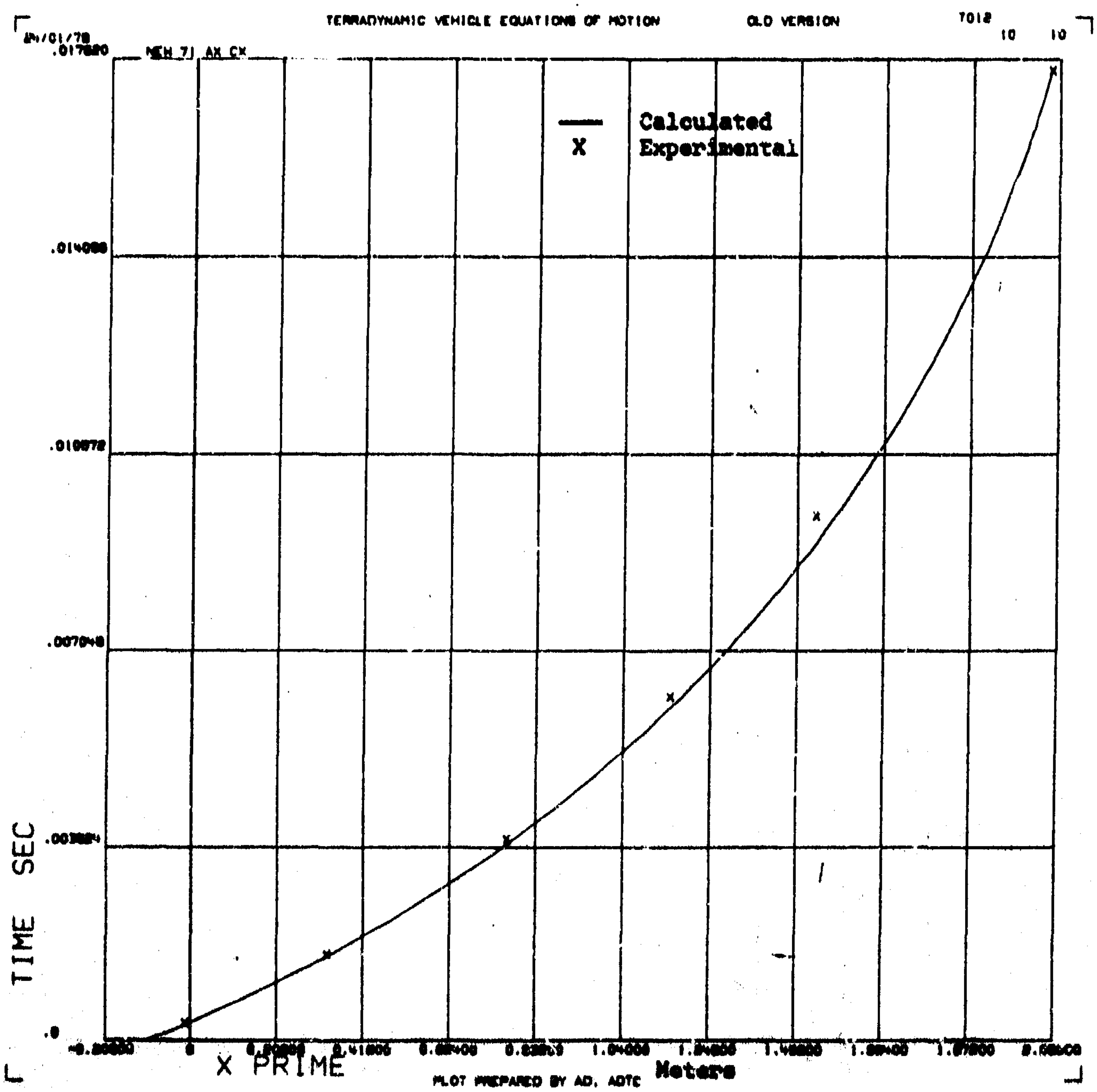


Figure 19. Time Versus Depth of Penetration for Shot No. 71. (A_XC_X Model)

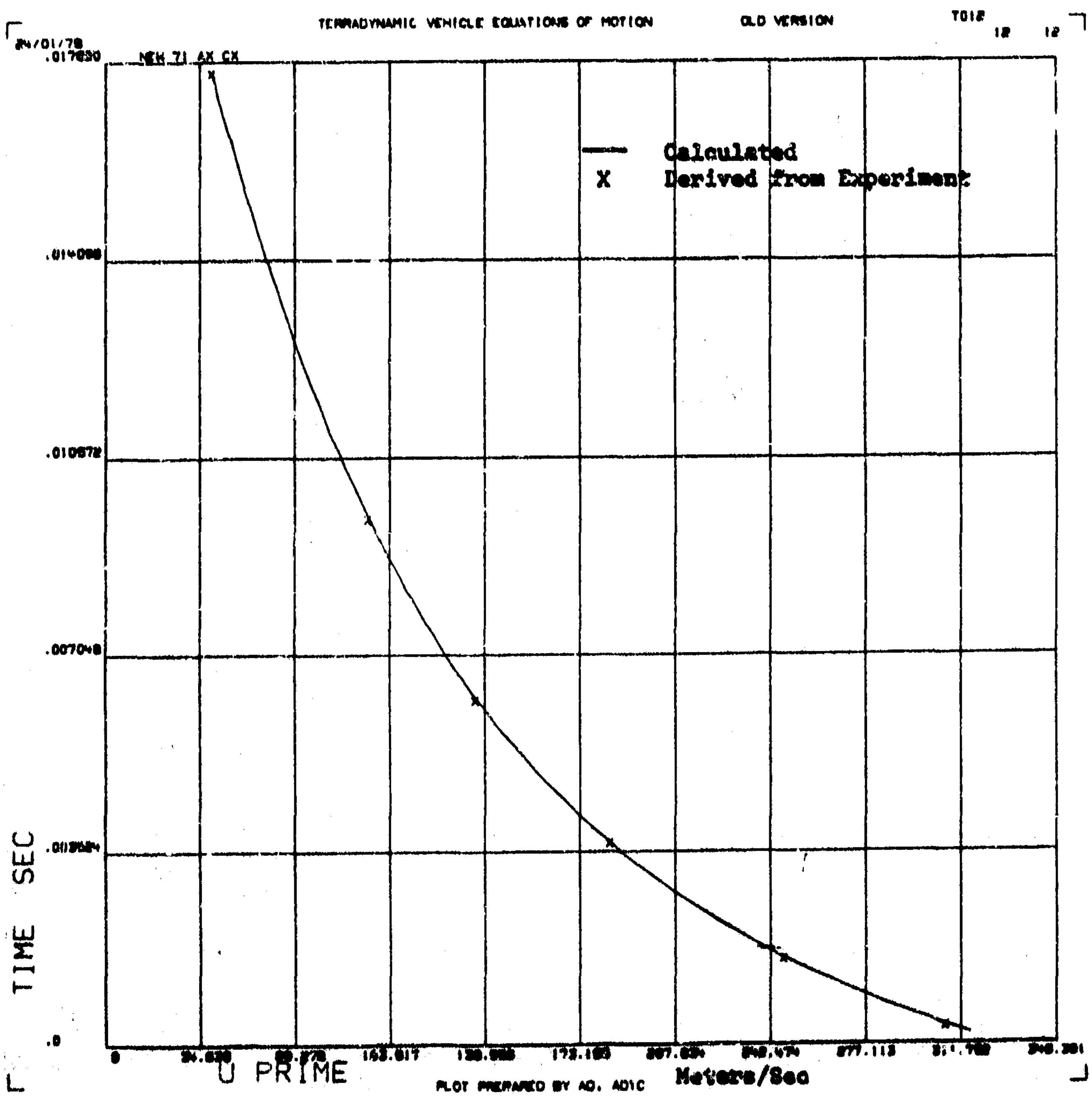


Figure 20. Time Versus Velocity for Shot No. 71. (A_x,C_x Model)

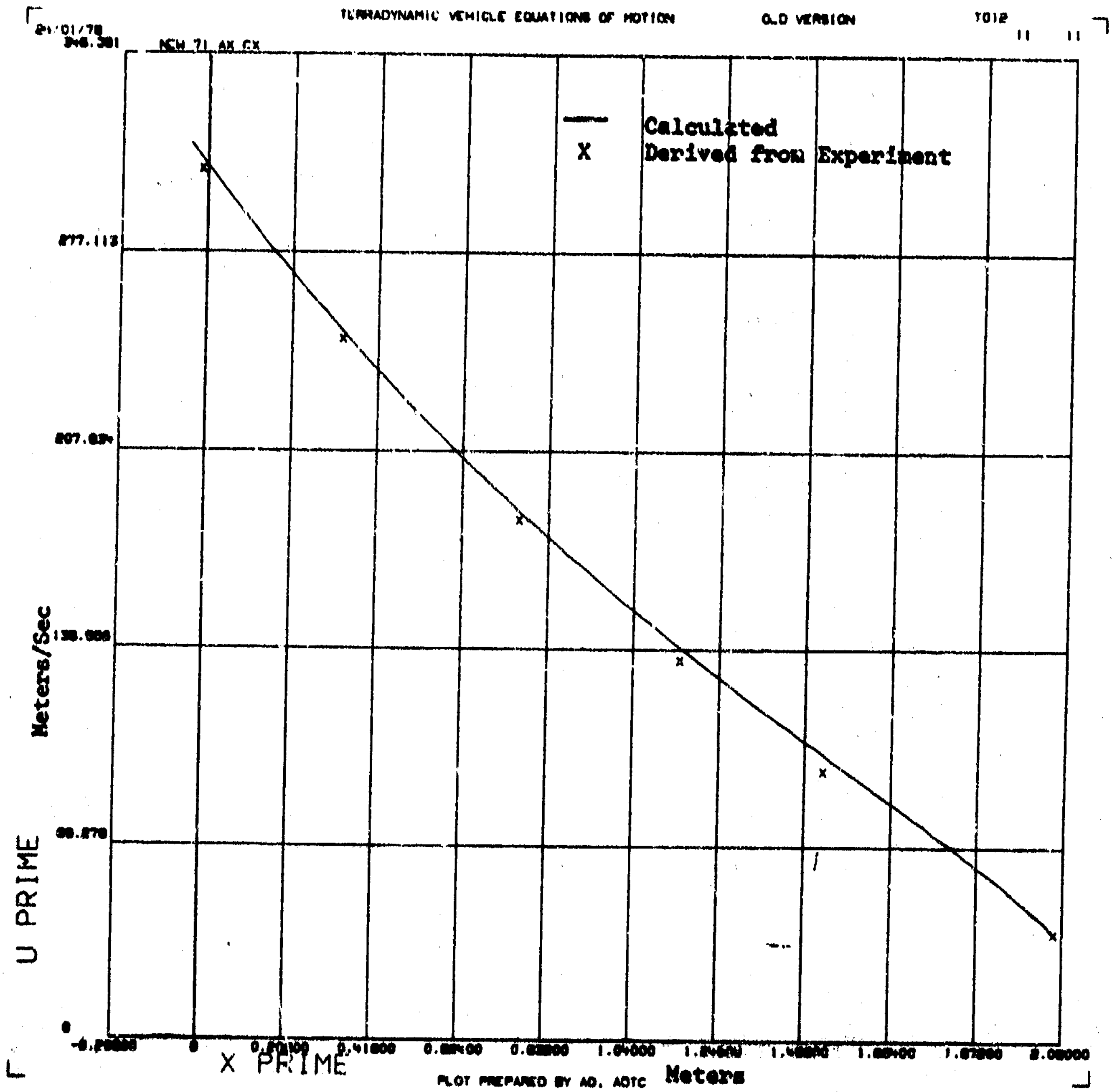


Figure 21. Velocity Versus Depth of Penetration for Shot No. 71. (A_X,C_X Model)

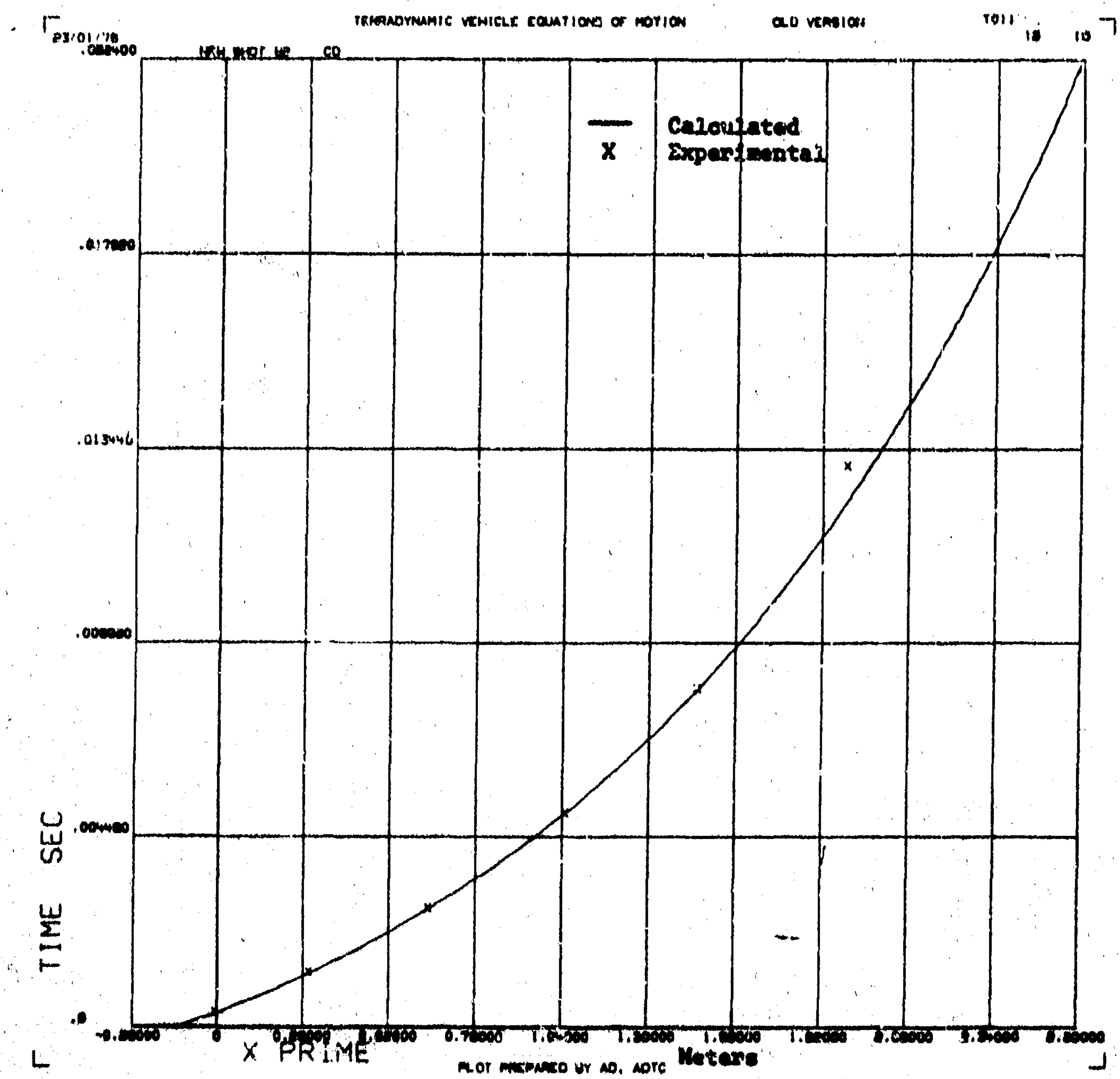


Figure 22. Time Versus Depth of Penetration for Shot No. 82. (C_D Model)

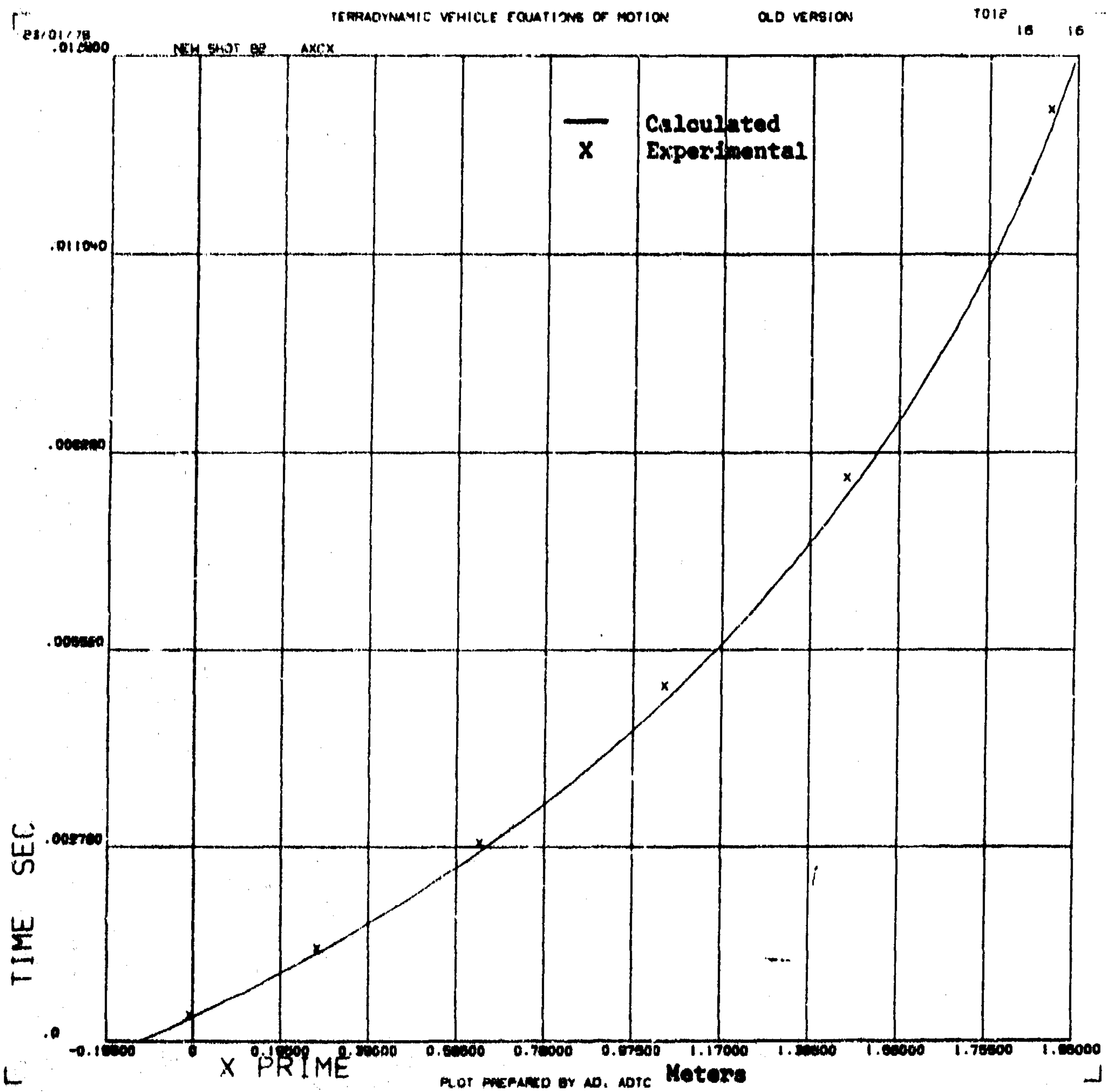


Figure 23. Time Versus Depth of Penetration for Shot No. 82. (A_x,C_x Model)

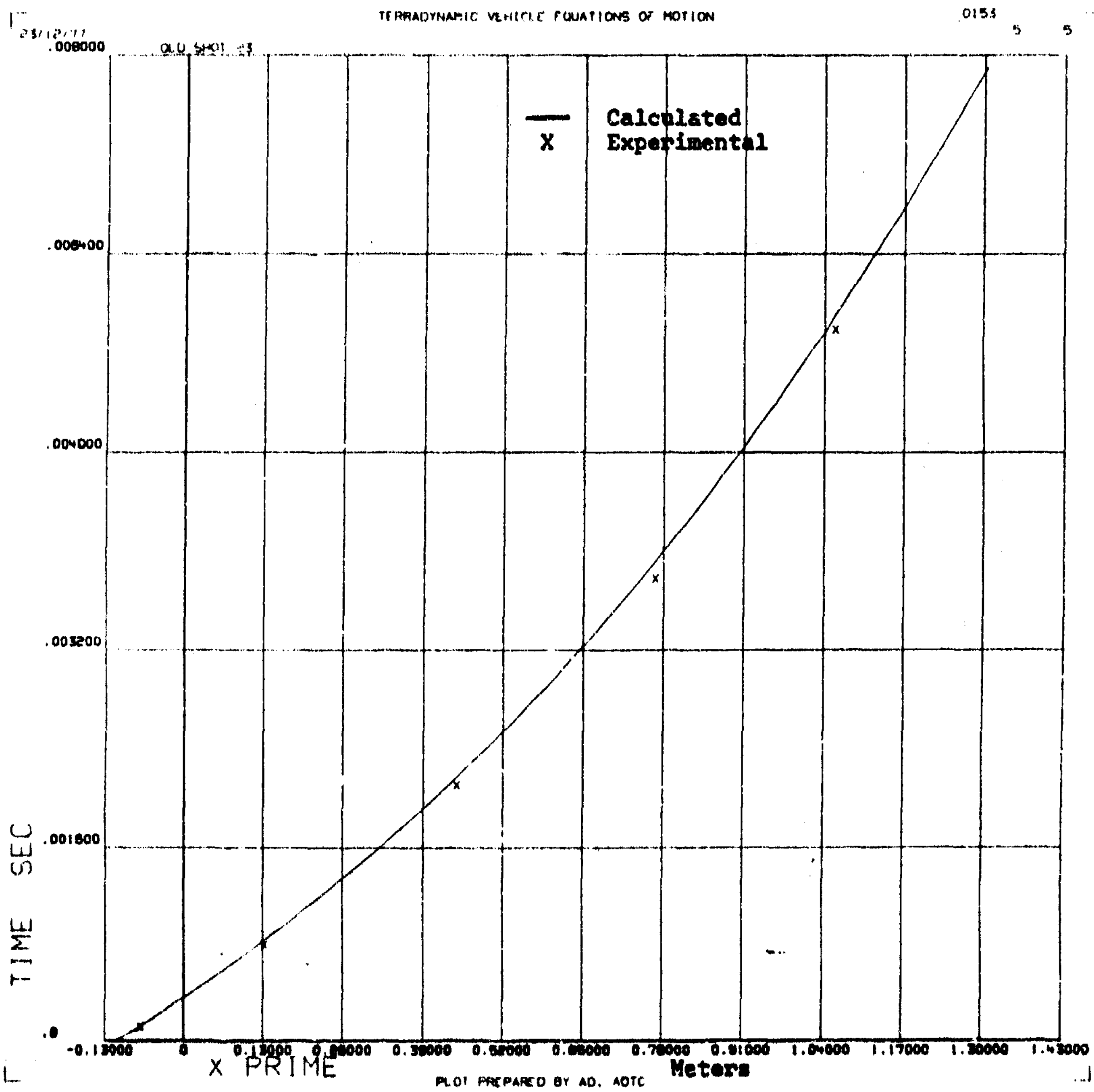


Figure 24. Time Versus Depth of Penetration of Shot No. 23 of Reference [2]. Expanding Cavity Model.

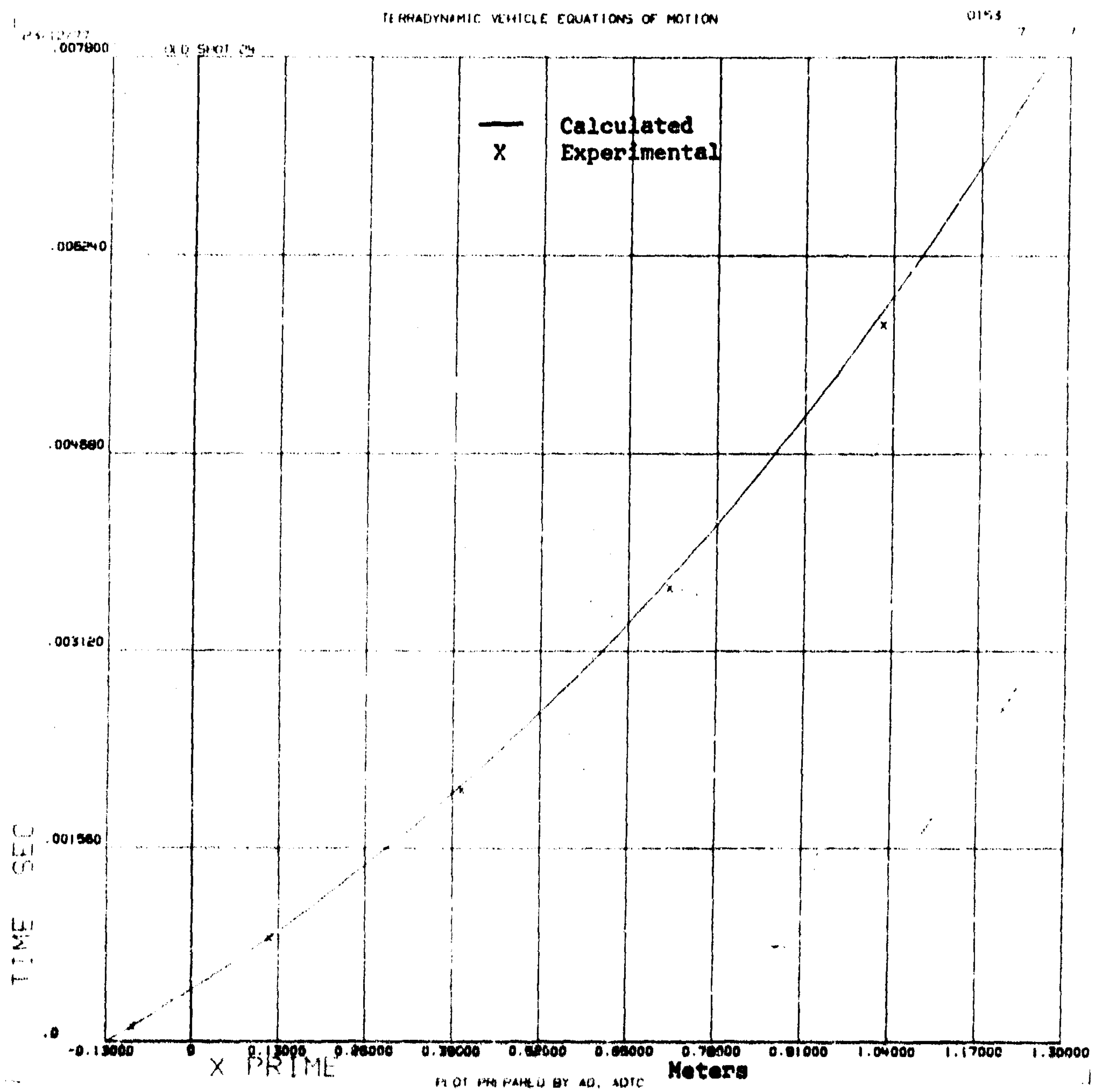


Figure 25. Time Versus Depth of Penetration of Shot No. 24 of Reference [2]. Expanding Cavity Model.

1.6 CAVITY EXPANSION MODEL APPLIED TO OBLIQUE IMPACT OF CONICAL FALSE NOSE

In 1975 Bernard and Hanagud [10] published a report extending the approximate penetration calculation method for projectiles with a hemispherical nose, based on the theory of expansion of a spherical cavity(CET), to projectiles with conical and ogival noses and showing how it could be extended to an arbitrary axielly symmetric projectile. The first use of CET methods for dynamic penetration was by Goodier [11] for a spherical projectile impacting an incompressible strain hardening target. Hanagud and Ross [12] modified the method to account approximately for target compressibility by treating the target material as a locking medium. The method has been applied to penetration calculations for flat-nose projectiles by Rohani [13], with the implicit assumption that a false hemispherical nose of target material is formed and carried by the projectile along a stable straight path.

The present investigators applied the method to flat-ended projectiles at normal incidence by assuming a false conical nose of length L and diameter D for several assumed values of L/D [2]. For L/D = 0.5 the conical nose gives the same results as a hemispherical nose. With an assumed false conical nose having L/D = 0.4 the details of the deceleration history were remarkably well predicted for the horizontal shots analyzed, using statically determined target material properties. An assumed hemispherical nose, or an assumed cone with L/D = 0.5 also gave fairly good agreement, but any attempt to apply the procedure directly to the flat nose, a cone with L/D = 0 would greatly overpredict the drag and underpredict the penetration.

Bernard and Hanagud [10] also considered briefly a conical nose at oblique incidence. The procedure given below is similar to their estimation of the pressure variation over

the nose. In the following procedure the entire conical nose is assumed to be in contact with the sand, but the afterbody is assumed not to be in contact anywhere.

According to the spherical cavity expansion theory for an infinite locking compressible medium the compressive normal stress p at the cavity surface is

$$p = p_s + p_I = p_s + \rho_p \; (B_1 a\ddot{a} + B_2 \dot{a}^2) \tag{27}$$

where p_s and p_I are the separate contributions of the material deformation (shear) and inertia, which Bernard and Hanagud [10] call the shear resistance and the dynamic pressure, respectively. In this equation ρ_p is the locked plastic density in the region behind the expanding spherical plastic locking shock wave, a is the instantaneous cavity radius, $\dot{a}$, and $\ddot{a}$ are the radial velocity and acceleration of the cavity surface and p_s, B_1, and B_2 are parameters related to properties of the material. The way these parameters are calculated for Eglin sand was presented in Reference [2]. It was found there that the term $B_1 a\ddot{a}$ was negligible in the application to the penetration at normal incidence, and the present treatment omits it from the outset.

Following Bernard and Hanagud [10], it is assumed that for the conical nose the velocity dependent part of the dynamic pressure p_I depends on the particle velocity V_p of the sand in contact with the nose, in the same way that p_I depends on $\dot{a}$ in the cavity expansion Equation (27). The particle velocity is given by $V_p^2 = V_n^2 + V_t^2$, where the component normal to the nose surface must be equal to the normal component of the nose surface velocity at the point. Again following Bernard and Hanagud, the tangential velocity component of the sand is assumed to differ from the tangential velocity component of the nose surface at each point of contact by a factor that varies from unity at the apex of the cone to zero at the base.

$$(V_t)_{sand} = \sqrt{1 - X}\ (V_t)_{nose} \tag{28}$$

where

$$X = (\bar{x} - x)/L_N . \tag{29}$$

Here $\bar{x} - x$ is the perpendicular distance along the axis of the cone measured back from the nose to the plane containing the point of contact. See Figure 11, Sec. 1.5. The x, y, z-axes are body axes centered at the projectile center of gravity as in Section 1.5.

For motion in an inertial x'z'-plane parallel to the xz plane of the body axes the foregoing assumption leads to

$$V_p^2 = U^2[1 - X\cos^2\gamma] + (W - Qx)^2\ [1 - X(1 - \cos^2\gamma\ \sin^2\beta)] + 2XU(W - Qx)\cos\gamma\ \sin\gamma\ \sin\beta\ , \tag{30}$$

where U and W are projectile x and z translation velocities, $Q = \dot{\theta}$ is the rotational velocity around the y-axis, γ is cone apex half angle, and β is the azimuth angle in the yz-plane, measured from the y-axis toward z-axis. With the pressure variations assumed as discussed above [with $B_1 = 0$], integration over the surface of the conical nose then leads to the following two components for the total force on the nose

$$F_x = -\tan^2\gamma\iint[p_s + \rho_p B_2 V_p^2]\ (\bar{x} - x)\ dx\ d\beta \tag{31}$$

$$F_z = -\tan\gamma\iint[p_s + \rho_p B_2 V_p^2]\sin\beta\,(\bar{x} - x)\ dx\ d\beta \tag{32}$$

with V_p^2 given by Equation (30). The calculation of the pitching moment is complicated by the variation of the local z-component velocity $w = W - Qx$. Since the nose-length L_N is small compared to the length L_1 from the center of gravity of the projectile, the simplifying assumption was made that for the small angles of attack the total force F_z acts through the volume centroid of the conical nose. Thus the pitching moment M was approximated by

$$M = (L_1 + \frac{1}{4}L_N)\ F_z . \tag{33}$$

Since suitable transient experimental data with actual conical nose projectiles was not available for comparison with

trajectory predictions using this formulation, calculations were made for several of the flat-ended projecules used in the previous experimental program [2], again assuming a false conical nose with L/D = 0.4. It was realized that this assumption might not be so good for incidence angles slightly oblique to the intended x-direction of propagation as it had proved to be for normal incidence, since the vertical F_z force would tend to push the false nose off the projectile, or at least to cause it to be asymmetric.

The trajectory calculations used the three-dimensional rigid-body dynamics code of Section 1.5. The cavity expansion theory parameters used were those previously determined for Eglin sand [2], namely

$$\left.\begin{aligned} p_s = 3.396 \text{ MPa} \;, \quad \rho_p = 1700 \text{ kg/m}^3 \\ B_2 = 1.013 \quad \text{(dimensionless)} \end{aligned}\right\} \qquad (34)$$

Calculations were made for horizontal Shots No. 17, 19, 25, 63 and 64 of Reference [2]. The initial trajectory was assumed to be horizontal at the point of impact, but with the projectile angle of inclination θ as recorded at the first X-ray station. The initial angular velocity $Q = \dot{\theta}$ was estimated by comparing the calculated vertical velocity components of the nose and of the center of gravity as tabulated in Reference [2]. In the present calculation the vertical z'- components are positive downward while in the tabulation cited the vertical component was the y-component [positive upward]. The vertical nose and center of gravity components were calculated in that reference by cubic interpolation formulas separately fitted to the nose and center of gravity positions as recorded at the five X-ray stations.

Calculated results are compared with the experimental results in Table IX. The calculated center of gravity positions are in surprisingly good agreement with the observations, especial-

ly the x' values, for which the largest error at the last station was only 6 percent in Shot 17, and 2 percent or less for the other four shots analyzed. The vertical position calculation gave errors of -24%, -31%, +13%, -6% and -46%, respectively, in Shots 17, 19, 25, 63 and 64. The horizontal velocity errors at the last station were -7%, +0.2%, +4%, +24%, and +19%, respectively. It may be noted that the velocities labeled U'_{exp} were obtained by differentiating the one-parameter Poncelet model fitted to the data [2].

The calculation, however, consistently overestimated the angle of inclination, by more than a factor of two in Shots 25 and 63. This may be a result of afterbody forces, which were neglected in the calculation, assuming no reattachment. The sand separation angles as measured on each X-ray negative were tabulated in Reference [2]. The separation angles above and below for the last station are given at the end of the results for each shot in Table IX. The upper separation angles are in the range of 9.5° to 11°, while the lower separation angles are 1.5° or smaller [zero for Shot 25]. Even where a separation angle of 1° or so was recorded, there may be a substantial amount of sand in the turbulent separation region, which does not show up in the X-ray because the density is not great enough, but which may exert enough force on the afterbody behind the center of gravity to slow the development of the angle of inclination.

Because of the many assumptions that were made, the agreement found is more remarkable than the discrepancies. It is emphasized that these are not curve-fitting methods like those of Section 1.4 but predictions based on the highly oversimplified cavity expansion theory penetration model using statically measured soil properties.

Sonic velocity field tests are discussed in the following section.

TABLE IX TWO-DIMENSIONAL TRAJECTORIES BASED ON CAVITY EXPANSION THEORY

Units are seconds, meters, m/sec, and degrees

Horizontal Shot No. 17 — Approach Velocity 212 m/s

time	x'_{calc}	x'_{exp}	$\Delta z'_{calc}$	$\Delta z'_{exp}$	U'_{calc}	U'_{exp}	θ_{calc}	θ_{exp}
.000217	-.073	-.071	.0000	.000	199.8	200	1.53	1.5
.001307	.129	.140	.0005	.008	170.7	178	1.93	2.3
.003540	.455	.486	.0034	.015	131.0	139	4.06	4.0
.00622	.763	.816	.0120	.023	100.6	106	9.62	9.0
.00914	1.021	1.092	.0304	.042	79.6	86	20.44	12.5

Final sand separation angles: Above = 9.5°, Below = 1°

Horizontal Shot No. 19 — Approach Velocity 211 m/s

time	x'_{calc}	x'_{exp}	$\Delta z'_{calc}$	$\Delta z'_{exp}$	U'_{calc}	U'_{exp}	θ_{calc}	θ_{exp}
.000202	-.066	-.068	.0000	.000	204.8	205	2.03	2.0
.001273	.140	.141	.00062	.007	174.48	180	2.60	3.3
.003323	.447	.464	.004	.015	136.5	140	5.22	7.0
.005932	.756	.783	.015	.030	105.3	104	12.31	12.0
.009099	1.051	1.072	.043	.062	82.15	82	28.68	16.5

Final sand separation angles: Above = 11°, Below = 0.5°

Horizontal Shot No. 25 — Approach Velocity 406 m/s

time	x'_{calc}	x'_{exp}	$\Delta z'_{calc}$	$\Delta z'_{exp}$	U'_{calc}	U'_{exp}	θ_{calc}	θ_{exp}
.000121	-.092	-.087	.0000	.000	387.2	381	.20	0
.000681	.119	.118	.0002	.005	330.7	335	1.40	2.0
.001703	.412	.417	.002	.011	265.6	266	3.94	3.5
.003009	.716	.726	.008	.013	211.2	207	9.58	7.0
.004613	1.016	1.024	.025	.022	170.0	177	22.32	9.0

Final sand separation angles: Above = 10°, Below = 0

Horizontal Shot No. 63 — Approach Velocity 415 m/s

time	x'_{calc}	x'_{exp}	$\Delta z'_{calc}$	$\Delta z'_{exp}$	U'_{calc}	U'_{exp}	θ_{calc}	θ_{exp}
.000146	-.069	-.071	.0000	.000	342.3	342	2.55	2.5
.000683	.106	.109	.0006	.002	301.5	312	3.13	3.5
.001708	.376	.396	.003	.002	247.8	259	5.57	8.0
.003084	.684	.711	.013	.012	198.48	196	12.59	11.5
.004798	.986	.989	.036	.034	162.26	131	28.8	11.5

Final sand separation angles: Above = 11°, Below = 1°

Horizontal Shot 64								Approach Velocity 409 m/s
time	x'_{calc}	x'_{exp}	$\Delta z'_{calc}$	$\Delta z'_{exp}$	U'_{calc}	U'_{exp}	θ_{calc}	θ_{exp}
.000146	-.078	-.080	.0000	.000	351.1	349	1.02	1.0
.000674	.102	.099	.0002	.004	308.3	316	1.26	1.5
.001693	.378	.386	.0015	.005	252.3	258	2.27	5.0
.0031	.690	.704	.005	.008	200.5	192	5.23	10.0
.0048	.992	.978	.015	.028	160.2	135	12.26	9.5
Final sand separation angles: Above = 11°, Below = 1.5°								

1.7 SONIC VELOCITY FIELD TESTS IN SOIL

1.7.1 Introduction

In the classical problem of sound propagation in an infinite or extended elastic medium only two possible solutions appear, waves of dilatation and waves of distortion, However, for finite media, waves associated with the boundary also appear as solutions to the wave equation. Lord Rayleigh and H. Lamb, references [14, 15] have shown, in considering the problem of sound waves in an elastic half space, that three distinct waves appear as solutions. In addition to dilatation and distortion waves there exists a third kind of wave whose effect decreases rapidly with depth from the surface boundary and whose speed of propagation is less than that of the dilatation wave. It has, however, been shown that the speed of propagation of this third or Rayleigh wave is approximately equal to that of the distortion wave. The Rayleigh and distortion (shear) wave speeds are almost constant with change in value of Poisson's ratio. However, the dilatation or compression wave speed varies from approximately 1.5 times the shear wave speed at a Poisson's ratio of zero to almost ten times that of the shear wave at a Poisson's ratio of 0.5. It is reported in both references [14] and [15] that in earth tremors the major portion of the energy of such disturbances can be associated with Rayleigh waves, which account for approximately 66 per cent of the energy while the distortion waves and dilatation waves account for

the remaining 27 and 7 per cent, respectively. For practical purposes the soil and bounding atmosphere can be approximated by an elastic half space, and any tests to determine wave propagation would be expected to yield three separate wave speeds. However, because of the almost equal wave speeds of the Rayleigh and distortion waves, near field measurements of a disturbance in soil are not expected to yield three distinct waves.

In order to determine the speeds of propagation and any effects of frequency on the speed of propagation in Eglin sand a series of tests were conducted using a blow from a hammer and plate device as well as a mechanical vibrator. Test procedures, test results, discussion, and conclusions are given in the following sections.

1.7.2 Test Procedure

A series of tests were conducted on undisturbed Eglin soil, (sand condition: loose, medium coarse), in cooperation with the USAF Armament Lab, Eglin AFB, Florida. Unfiltered impulses from a hammer blow on an aluminum plate and signals from a 20 to 50 Hz mechanical vibrator were each monitored and recorded using a line of six geophones evenly spaced at intervals of 20 feet (6.1 m). A schematic of the test arragement is shown in Figure 26(a). Two separate wave speeds were determined from the unfiltered impulse signals and one wave speed was obtained from wave packets obtained by turning on and off the 20 to 50 Hz mechanical vibrator. A plot of time of signal arrival versus distance is shown in Figure 27. The two wave speeds calculated from the slopes of the curves of Figure 27 were assumed to be a dilatation wave and a Rayleigh-shear combination wave. As discussed in the previous section the dilatation wave speed may range from 1.5 to as much as 10 times the shear wave speed while the distortion or shear wave speed and Rayleigh Wave speed are approximately equal.

A number of tests using a three-axis geophone and the hammer-plate device, as shown schematically in Figure 26(b), were conducted in order to examine the effects of filtering on the time of arrival for the three different pickups of the three-axis geophone.

In all tests, regardless of filtering process, the times of arrival of the signals and the magnitudes of the signals from the two horizontal, x and y, output channels were approximately the same. However, large variations in the magnitude of the signals and difference in arrival times of the signals were found to occur between the outputs of the vertical z and the longitudinal x channels. With both the x and z channels pass-band filtered between 40 and 50 Hz the arrival time of the longitudinal signal at the 100 ft (30.5 m) position precedes that of the vertical signal by about 120 msec. Approximately the same delay between the two signals is found when the longitudinal geophone is pass-band filtered between 40 and 5000 Hz and the vertical geophone is pass-band filtered 40 and 60 Hz. However, when both the longitudinal and vertical geophones are pass-band filtered between 4 and 100 Hz and also between 30 and 2000 Hz, the arrival times of both signals are about the same, with the longitudinal component leading by approximately 10 to 50 msec.

It appears from the experimental data that the vertical geophone responds to the high frequency components of the impulse, while the horizontal geophones respond to both low and high frequency components. The three axis geophone was placed about 1.0 ft (0.3 m) below the surface of the ground and at different distances [20 to 200 ft (6.1 - 61.0 m)] from the source. For this arrangement the vertical axis is almost perpendicular to the line from the source to the geophone, so that its response to a dilatation wave would be expected to be much

less than the response of the x-axis geophone, which is almost perpendicular to the wave front. However, it was observed that at frequencies where the wavelengths were less than the depth, the magnitude of the vertical component and the horizontal x-component were comparable. For example, an experimental test at a distance of 40 ft. (12.2 m) from the source showed the longitudinal geophone output signal to be six times that of the vertical geophone output when both output signals were pass-band limited between 3 and 30 Hz. For the same distance from the source and with both vertical and horizontal geophone output signals pass-band limited between 3 and 100 Hz the magnitude of the longitudinal geophone output was approximately twice that of the vertical geophone output. In the case where both vertical and longitudinal signals were pass-band limited between 3 and 3000 Hz both magnitudes were approximately equal.

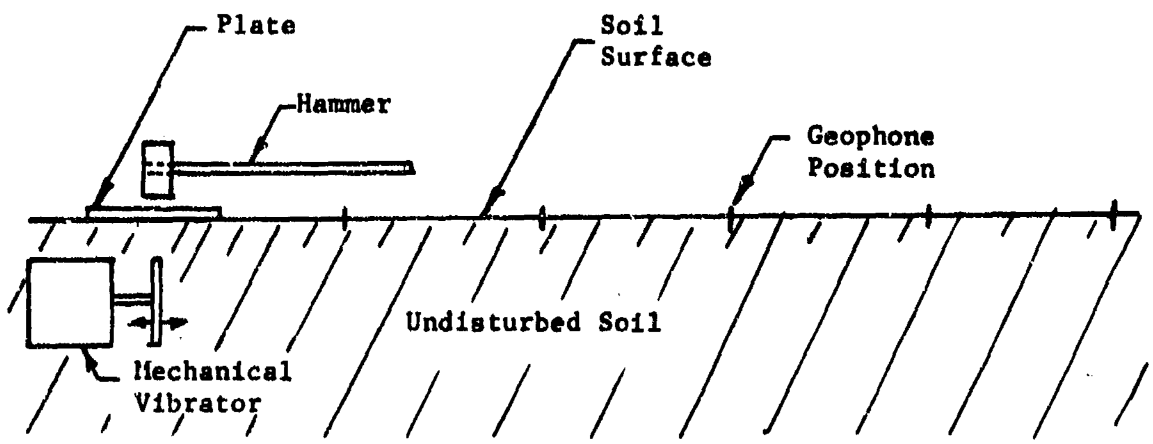
1.7.3 Discussion and Conclusions

As discussed in Section 1.7.1 a disturbance produced at or near the surface of the soil will generally produce three separate waves, that is, a dilatation wave, a distortion wave and a Rayleigh wave in order of decreasing speed of propagation. Far field measurements have shown the presence of these three waves. However, in near field measurement the three separate waves are not distinguishable from one another and changes in wave frequency produce discernible differences in measured wave speeds. Measurements made at the various frequencies on both single axis geophones (Figure 27) and three axis geophones indicate a basic slow low frequency wave assumed to be a Rayleigh-shear wave and a faster dilatation wave of increasing wave speed with increasing frequency. The results of all the tests are summarized in Figure 28, which shows a range of wave speeds varying from approximately 300 to 630 ft/sec (91.5 to 192.1 m/sec). The low frequency Rayleigh wave appears

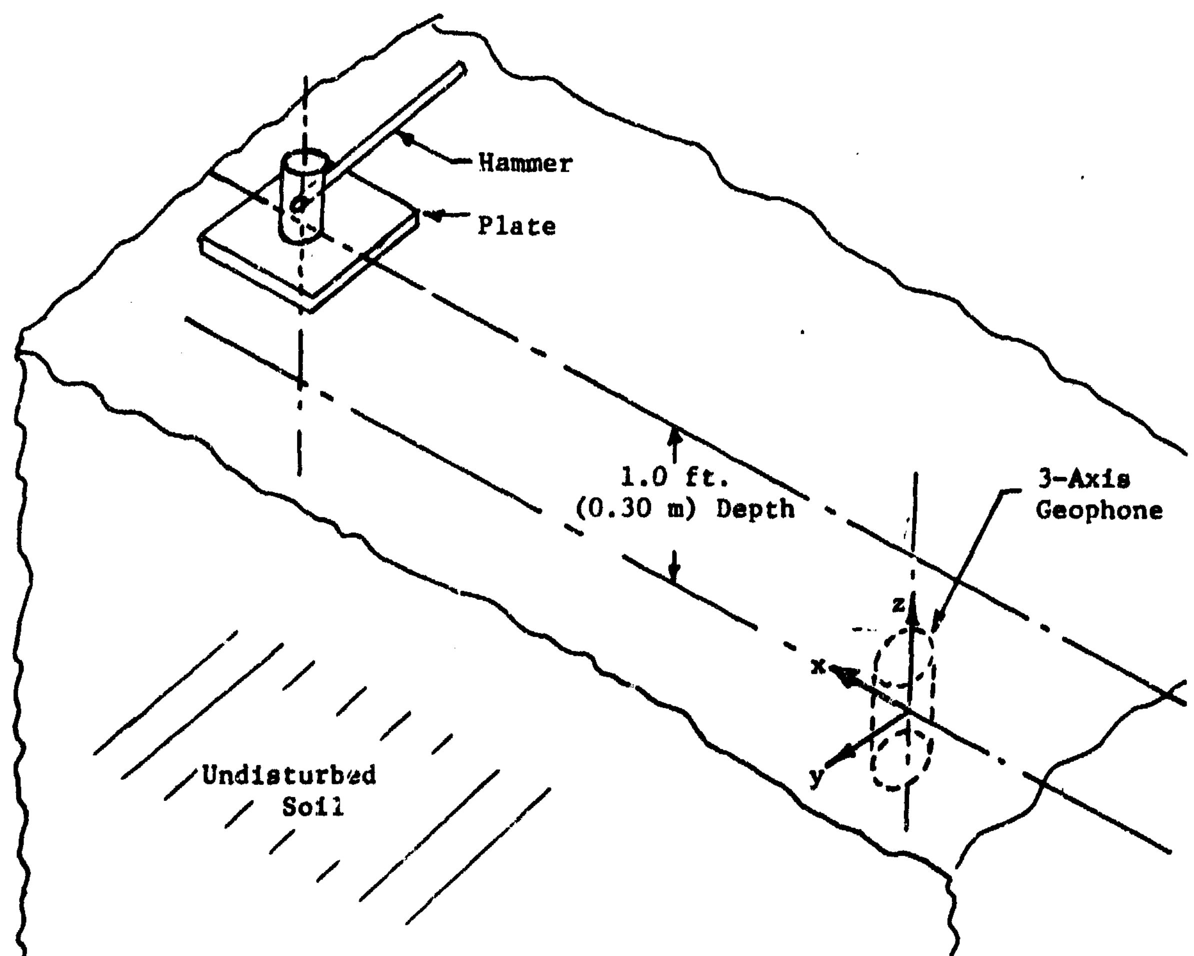
to carry the larger portion of the energy (based on comparison of magnitudes), which is in agreement with the observations reported in reference [14]. The predominant longitudinal wave found at the lower frequencies is also in agreement with results reported in reference [15], which indicate that the horizontal component of the Rayleigh wave is parallel to the wave propagation direction. The slow or Rayleigh-shear wave speed appears to be frequency independent as evidenced by the varying delay in signal arrival time of the two waves with no appreciable change in arrival time of the second wave.

The overall results of the tests lead to the following conclusions:

1. For the medium coarse Eglin sand tested, sonic speeds are reasonably low, ranging from 300 ft/sec (91.5 m/sec) at lower frequencies to 630 ft/sec (192.1 m/sec) at higher frequencies.
2. Two separate wave speeds are clearly discernible at frequencies up to 2000 Hz, that is, a slow or Rayleigh-shear wave speed independent of frequency and a dilatation wave speed which increases with increasing frequency.



a) Test arrangement for single axis geophones.



b) Test arrangement for 3-axis geophone

Figure 26. Test arrangements for sonic speed measurements.

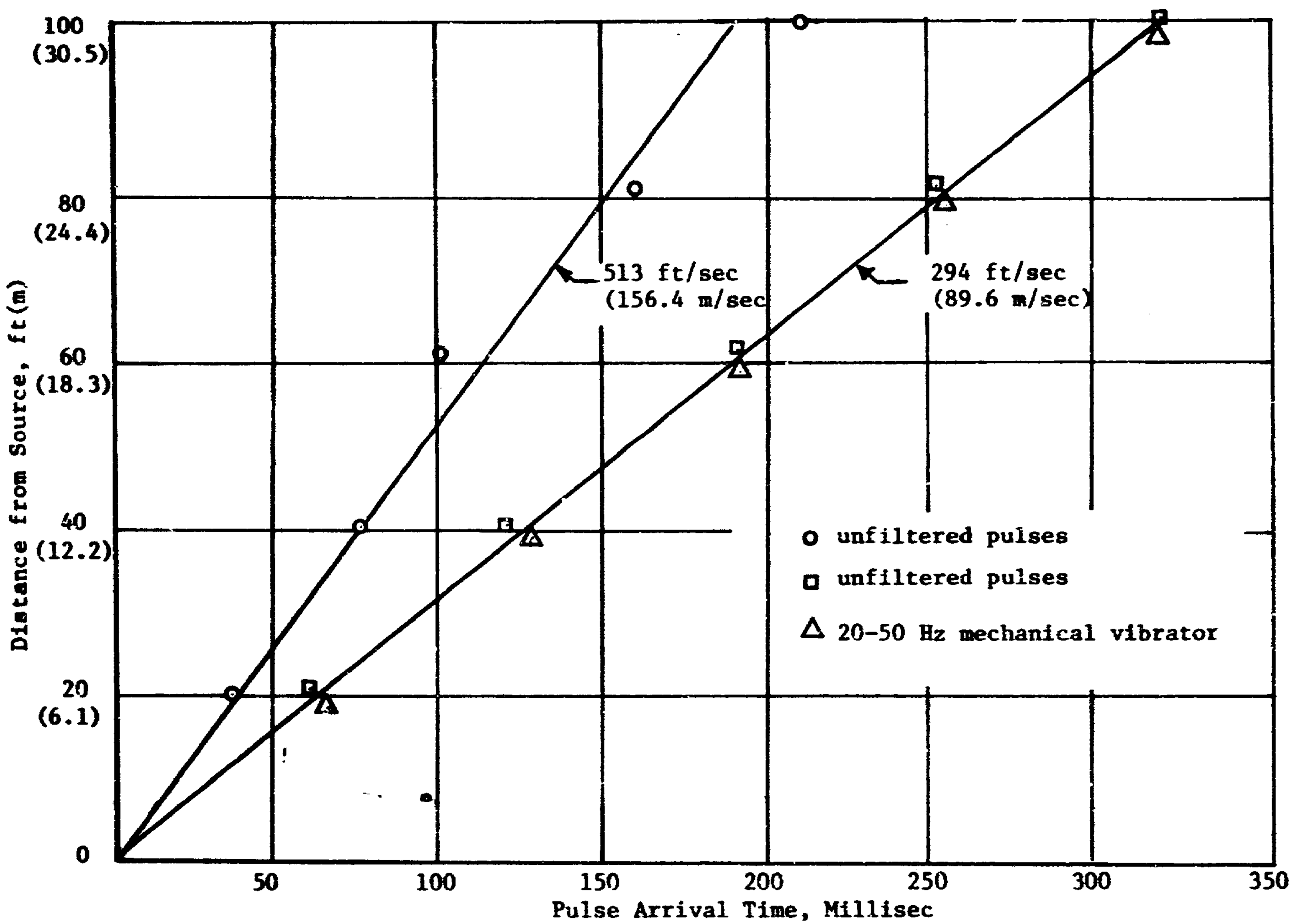


Figure 27. Time of arrival of unfiltered pulses versus distance from sources.

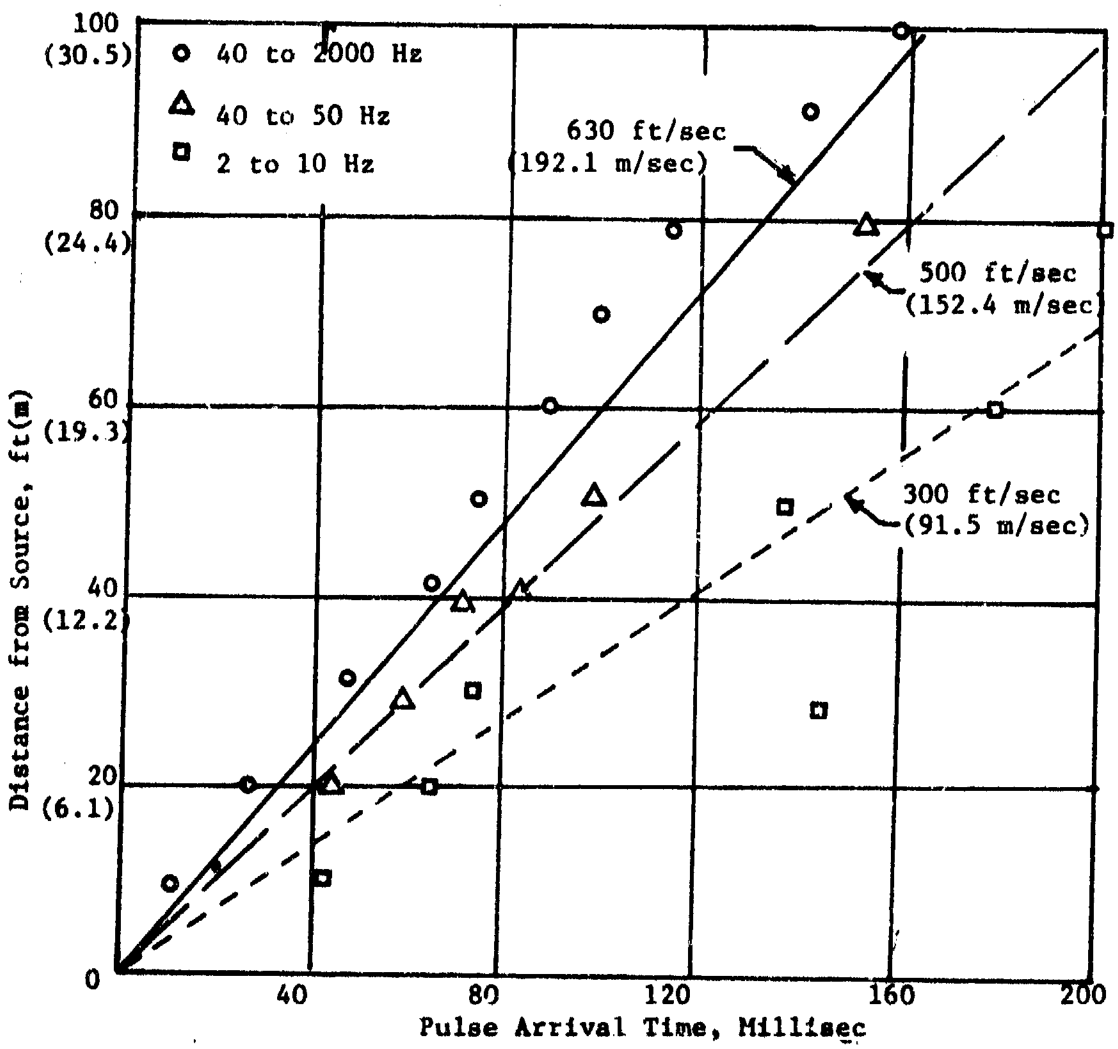


Figure 28. Time of arrival of filtered impulses versus distance from source. Source: hammer and plate.

1.8 SUMMARY AND CONCLUSIONS

The Eglin experimental penetration studies of vertical firings into sand were described in Sections 1.2 and 1.3. Classical analysis of the results in Section 1.4 showed that a two-parameter Poncelet force law giving a deceleration $A + BV^2$ could fit very closely the observed portion of each stable approximately straight trajectory. While there was a considerable scatter in the values of B obtained with one projectile type in different shots [see Table VI of Section 1.4] there was no consistent variation with impact speed, so that a model with a constant B [for a given projectile and target] seems appropriate for fitting the whole trajectory. Higher values for A were, however, found at higher impact speeds. Possibly a model including also a term proportional to V would give better fits with constant values of the three parameters. Such a three-parameter model was not used in the present investigation.

No significant difference was found in the one-parameter Poncelet drag coefficients between the vertical tests of the present program and the horizontal tests previously reported in Reference [2], indicating that for the moderate depths involved [less than 2.5 meters] gravitational effects on the penetration distance were negligible. In the horizontal firings the test chamber was open at the top, which was believed to account for a fairly consistent slight upward trend to the horizontal trajectories.

The three dimensional dynamic code was applied in Section 1.5 to the one-dimensional trajectories of several of the vertical shots using differential area force law coefficients based on the one and two parameter Poncelet force laws with parameter values suggested by the results of Section 1.4. The differential area forces were assumed to act

over the surface of a conical false nose of length to diameter ratio 0.4 as suggested by previous results for horizontal firings in Reference [2] based on the cavity expansion theory. The results were in consistently good agreement with the experimental data.

The three-dimensional code was also applied in Section 1.6 to five of the two-dimensional experimental trajectories Reference [2], using differential area force law parameters based on the cavity expansion theory penetration model with an assumed conical false nose of length to diameter ratio 0.4. The penetration distance versus time was remarkably well predicted. The predictions of the lateral deviation from a straight trajectory were only fair, and the final inclination angles were consistently overpredicted, probably because of the neglect of afterbody forces. The three dimensional code shows promise, but these investigations have not yet demonstrated the ability to predict a full three-dimensional trajectory, primarily because of the lack of suitable assumptions about the variation of the differential area forces over the projectile.

In the sonic velocity field tests in Eglin sand two separate wave speeds were clearly discernible at frequencies up to 2000 Hz, a slow or Rayleigh-shear wave speed of about 300 ft/sec (91.5 m/sec) and a dilatation wave speed which increases with frequency up to about 630 ft/sec (192.1 m/sec).

SECTION II

STUDIES OF SPALL CHARACTERIZATION OF CONCRETE

2.1 INTRODUCTION

The general subject of hardened structures subjected to blast loads requires information on the dynamic properties of materials to better understand the failure/fracture characterization of such structures. In the case of concrete, the inherently low tensile strength plays a major role in determining the potential resistance to spall of typical structural components such as concrete slabs. Studies on the dynamic properties of concrete are relatively limited and information on this subject area is needed for establishing breaching/penetration predictions which are desirable. In a recent report, reference [16], it has been shown that the ultimate dynamic tensile strength of concrete varies with strain rate and that a static strain energy theory appears to provide a reasonable fracture criterion for design purposes. Thus, the critical strain energy may potentially be used as a screening measure for selecting specific materials for spall resistant situations. It is the purpose of the present investigation to further explore this theory by studying the fracture of concrete rods.

2.2 CONCRETE ROD PREPARATION

The impacted concrete specimens used in this research were 18 inches long by 1.5 inch diameter cylinders (45.72 cm x 3.81 cm). Specimens were cast using a Type 1 Portland cement with two aggregate sizes, specifically an 8-30 and 30-65 Edgar sand obtained from KL Industries, Edgar, Florida. A sieve analysis of the aggregates used was performed and the grain size distributions obtained shown in Figure 29. The uniformity coefficients C_u for the sands tested were found to be 2.0 and 2.65 respectively. Figure 30 is a photograph of the sieves and shaker used for the analysis described.

A mix of two parts aggregate to one part cement was used to provide the desired high strength properties. The specific water-cement ratio used for each aggregate type was determined by trial to provide uniform bars with the smoothest possible surface on which to apply strain gages. Table X summaries the particular water/cement (w/c) and sand/cement (s/c) ratios used for the specimens tested here.

TABLE X

COMPONENT SPECIMEN MIX PROPERTIES

Aggregate Type	w/c	s/c
A-2/30-65	0.58	2.0
A-4/8-8-30	0.53	2.0

The molds in which the specimens were cast consisted of PVC tubes split longitudinally for ease of bar removal (Fig.31). To prevent leakage of water from the fresh concrete the seam was sealed with duct tape, and rubber stoppers inserted at each end of the bar and sealed with electrical tape. Masking tape was also wound around the mold to provide lateral support against expansion of the concrete (Fig.32).

A systematic description of the steps used in producing a typical sample is given below for completeness. First, the aggregate, cement, and water were proportioned by weight to a precision of $\pm$ gram. Next the cement was placed in a HOBART mixer, (Fig. 33), with aggregate added until a uniform mix was obtained. Water was added to this mixture, with mixing continued until a uniform mixture was obtained. The PVC molds for fabricating the bars were then assembled, with a stopper placed at one end of the mold assembly and the inside of the PVC tubing coated with a thin film of oil to prevent adhesion of the cement to the mold. Next the concrete was poured into the mold in approximately 2 to 3 inch thick layers; each layer being tamped approximately 20 times with a 1/2 inch diameter (1.27 cm)

fiberglass rod. The remaining rubber stopper was then inserted into the mold assembly and taped to prevent leakage. The specimen was then laid horizontally for initial set for a period of twenty-four hours. Finally the concrete bar was removed from the mold and placed in a curing room until time for testing.

2.3 IMPACTOR SAMPLE PREPARATION

The machined projectiles used to impact the concrete bars in these studies consisted of several different types of materials and nose configurations. The specific material types tested included steel, copper, aluminum, brass, teflon and rubber while the nose shapes investigated included hemi-spherical, inverted ogive, conical frustum and rounded noses. All specimens tested were nominally one inch long by 0.382 inches in diameter (2.54 cm x 0.97 cm). The purpose of testing a wide variety of material impactors and nose shapes was to establish information on the bounds of the critical strain amplitudes necessary to produce essentially constant strain rates and controlled pulse rise times. For the instrumented bar tests copper and steel impactors were used exclusively with the majority of the tests conducted using copper impactors because of the range of controlled compressive wave rise times obtainable using this type of impactor (30-70 msec).

2.4 EXPERIMENTAL SET-UP

An air gun impact facility was used to apply a single non-repetitive impact loading to the cylindrical concrete specimens tested here. Strain pulses generated from bar impact were measured from strain gages bounded to the surface of the specimens using Epoxy cement (BLH EPY 150). The gages used were BLH, FAP-12-12S6 bonded to the surface of the specimens following the gage preparation procedures described in

reference [17]. Strain gages were positioned on the concrete bar specimens as shown in Fig.34 in order to obtain information on fracture in the vicinity of the strain gage stations. Normally four gages located near the distal end of the impacted bar were used to record test information. However, for each bar aggregate type and cure time one representative specimen was tested with a front gage, Fig.34a, to more accurately monitor wave speed in the bar. The electronic equipment used in the experimental set-up is described below. A special strain gage bridge circuit used in conjunction with Tektronix Type 1A7A differential amplifiers were used as a preamplifier circuit for a Tektronix Type 556 oscilloscope. The transient dynamic strain pulses were recorded photographically using Polaroid Type 667 film with the oscilloscope set in the single sweep trigger mode. A crystal transducer mounted on the surface of the specimen near the impact end was used to generate trigger pulses for the oscilloscope. The delayed triggering function of the oscilloscope was used to avoid displaying excessive amounts of baseline trace before the strain pulse arrived at the strain gages.

The dynamic impacts on the concrete specimens were produced by an air gun assembly as shown schematically in Figure 35 and described in detail in reference[17].A photograph of the impact facility has also been included for completeness and is shown as Fig.36 . Impact velocity of the projectiles was controlled by regulating the air pressure in the inside and outside chambers of the air gun. For low pressure operation of the air gun, freon gas was used in order to take advantage of the low cylinder pressure and exercise controlled low pressure regulation.

The impact velocities were determined by measuring the time interval for the projectile to travel a measured 4 inches (10 cm) near the end of the gun barrel. Two light emitting diodes

(LED's) attached directly to the gun barrel produced light beams which were sequentially interrupted by the projectile. Phototransistors and appropriate circuitry gated a counter-timer instrument which displayed the time interval on a digital display.

In order to generate wave forms consistent with an essentially constant strain rate for each pulse rise time, and the necessary threshold energy to produce a critical fracture strain, projectiles of the type shown in Fig. 37 were used. The various lengths and nose shapes selected for the above projectiles ensured that the aforementioned requirements were met.

The concrete specimens tested were supported on semi-circular teflon supports which could be adjusted both laterally and vertically (see Fig. 38). Teflon supports were used in order to reduce friction between the test specimens and support mounts during testing. Each specimen was aligned to the bore of the gun barrel to ensure concentric impacts, and the complete test assembly was enclosed in a protective plywood box to contain concrete spall and projectile richochet (see Fig. 38).

2.5 RESULTS AND DISCUSSION

2.5.1 Static Tests

Compression and split tension tests were performed on the concrete specimens tested in order to determine the static Young's modulus and the static compression and tensile ultimate strengths. Specimens used for these tests were nominally 6 inches in diameter by 12 inches long (15.24 cm x 30.48 cm) and were prepared according to ASTM standards. All static tests were conducted using a Riehle, 100,000 pound capacity testing machine. (444,820 N)

For the axial compression test the specimens were capped

with a sulfur, fly ash mix to obtain a smooth test interface for load application. A mechanical gage was used in all compression tests for determining strains as shown typically in the test set-up of Fig.39 . A minimum of three tests for each bar type were performed and the stress-strain plots for each test recorded and then averaged. One of the typical plots obtained and used for data analysis is shown in Fig. 40. The mechanical strain gage was then removed, Fig. 41 and the load increased until fracture occurred.

Split tension tests were also performed on three specimens of each aggregate type; the set up being as illustrated in Fig. 42 . For these tests a BLH, FAP-50-12-56 strain gage was attached to the specimen for use in measuring the strain of the concrete specimens due to the applied tensile loading.

Density determinations were also made for all of the compression and split tension specimens tested. Table XI summarizes the static properties of the concrete used in this research.

TABLE XI

PROPERTIES OF THE CONCRETE

Aggregate	Curing time	Density lb/cuft	Compressive stress at failure psi	Tensile stress at failure psi	Young's modulus psi compressive
A-2	7	130 (2080kg/m^3)	5600 38.35 MPa	285 1.95 MPa	$3.0x10^6$ 20.55 GPa
A-2	28	130 (2080kg/m^3)	5300 36.30 MPa	265 1.82 MPa	$2.7x10^6$ 18.49 GPa
A-4	7	135 (2160kg/m^3)	7600 52.06 MPa	275 1.88 MPa	$3.9x10^6$ 26.71 GPa
A-4	28	135 (2160kg/m^3)	8100 55.4 MPa	265 1.82 MPa	$3.8x10^6$ 26.03 GPa

2.5.2 Dynamic Tests

Impact tests were conducted on the two aggregate types and the two cure cycle types (four different types of

Polariod photographs of the oscilloscope traces in either of two ways. When fracture occurred between gages, the strain-time histories for gages on either side of the fracture were used as a basis for interpolation of the fracture strain magnitude occurring at the specific fracture point. This fracture point was determined from post test inspection of the specimens as well as from recorded time history records of conducting stripes painted on the bars and discussed in a following section. For fracture occurring ahead of the lead gage for any of the strain gaged bars shown in Fig.34 a calculated time for the wave to reach the known fracture location and return to the lead gage was used to interpolate a fracture strain magnitude from the recorded strain-time history time of the lead gage. This could be further checked by noting the failure time of the conducting stripe. The use of the conducting stripe was further used to ascertain if failure occurred during initial tensile pulse passage or after repeated pulse passage along the bar specimen. For these cases where the latter occurred, the test was repeated in order that only fracture during initial tensile pulse passage was recorded. Other tests for which quantitative oscilloscope data were not recorded due to improper delayed triggering or bad film pack have been omitted from Tables XII and XIII.

In connection with the observations of fracture after multiple pulse passages, it was noted that this was more likely to occur in impacted bars having long compressive rise times. This also coincided with observations that initial triggering of the scope for obtaining oscilloscope traces was found to be more sensitive for longer pulse rise times.

In order to ensure that the bars were aligned properly for central impacts, selected bars had strain gages mounted 180° apart at the position of the lead gage. Strain time

TABLE XII
Concrete Fracture Data-Hemispherical Copper, Impactors

Bar #	Type	Gage Test Configuration	Impact Velocity	Impactor	Nose Shape	Rise Time	Fracture Strain	Fracture Energy	Fracture Description
92	A-2/7	a	37.33 m/sec.	Cu	H Sph	17.5	414	.38	16 mm behind gage 4
72	A-2/7	b	37.26	Cu	H Sph	22	362	.36	3 mm ahead of gage 3
93	A-2/7	c	37.23	Cu	H Sph	14	444	.348	38 mm ahead of gage 2
60	A-2/7	d	37.99	Cu	H Sph	12	417	.262	3 mm ahead of gage 3
42	A-2/28	a	37.13	Cu	H Sph	25	483	.79	32 mm ahead of gage 2
38	A-2/28	b	37.79	Cu	H Sph	22	517	.79	at gage 2 and .25 mm ahead of gage 1
22	A-2/28	b	37.31	Cu	H Sph	35	448	.95	35 mm ahead of gage 1
40	A-2/28	c	37.33	Cu	H Sph	18	500	.61	25 mm ahead of gage 4 16 mm ahead of gage 2
37	A-2/28	c	37.44	Cu	H Sph	24	555	.99	5 mm ahead of gage 2
39	A-2/28	d	37.57	Cu	H Sph	21	556	.875	41 mm ahead of gage 1
88	A-4/7	a	37.71	Cu	H Sph	17	448	.43	41 mm ahead of gage 2
86	A-4/7	b	37.57	Cu	H Sph	20	586	.86	at gage 2
78	A-4/7	c	38.22	Cu	H Sph	14	472	.389	28 mm ahead of gage 2, at gage 2
87	A-4/7	c	37.11	Cu	H Sph	12	522	.408	6 mm ahead of gage 4, 47 mm ahead of gage 2
80	A-4/7	d	37.87	Cu	H Sph	16	444	.394	19 mm ahead of gage

TABLE XII (continued)

Bar #	Type	Gage Test Configuration	Impact Velocity	Impactor	Nose Shape	Rise Time	Fracture Strain	Fracture Energy	Fracture Description
46	A-4/28	a	37.23 m/sec.	Cu	H Sph	15	483	.50	6 mm ahead of gage 3
45	A-4/28	b	37.69	Cu	H Sph	15	517	.57	6 mm ahead of gage 4
54	A-4/28	c	35.43	Cu	H Sph	19	375	.375	19 mm ahead of gage 3, at gage 3
55	A-4/28	c	37.18	Cu	H Sph	18	389	.390	32 mm ahead of gage 3
48	A-4/28	c	37.41	Cu	H Sph	24	359	.443	41 mm ahead of gage 2
51	A-4/28	c	37.69	Cu	H Sph	22	375	.443	32 mm ahead of gage 3, 38 mm ahead of gage 2
27	A-4/28	d	37.43	Cu	H Sph	16	472	.510	38 mm ahead of gage 1

TABLE XIII

Concrete Fracture Data-Other Impactor Nose Shapes and Materials

Bar #	Type	Gage Test Configuration	Impact Velocity	Impactor	Nose Shape	Fracture Energy	Fracture Description
91	A-4/7	c	37.36 m/sec.	C_u	RC	.23	25 mm ahead of gage 3
71	A-2/7	c	36.77	C_u	CF	.26	13 mm ahead of gage 2
58	A-4/7	d	36.39	C_u	CF	.29	16 mm ahead of gage 1
41	A-2/28	d	37.64	C_u	IO_g	.39	9 mm ahead of gage 1
29	A-2/28	c	37.49	C_u	IO_g	.37	29 mm ahead of gage 2
94	A-2/7	d	35.28	st	HSph	.23	25mm head of gage 1
23	A-2/28	d	35.25	st	HSph	.24	32 mm ahead of gage 1
36	A-2/28	d	34.72	st	HSph	.29	30 mm ahead of gage 1
28	A-4/28	d	34.95	st	HSph	.38	32 mm ahead of gage 3, 30 mm ahead of gage 1
26	A-4/28	d	33.62	st	HSph	.39	19 mm ahead of gage 2

history records of these gages showed minimal if any bending or secondary type wave perturbation on the principal compressive-tensile wave history record.

Wave speed data for the concrete bars tested were calculated from tests run using measurements from selected bar gage configuration as shown in Fig.34a. Of these the most reliable information on wave speed data is associated with configuration because of the greater distance between gage positions and consequently greater inherent accuracy in interpreting data from the photographed wave trace. These data are summarized in Table XIV and were used later in interpolating the position of compressive wave traces at fracture as well as in the fracture energy criterion to be described.

TABLE XIV

BAR WAVE SPEEDS

Aggregate Type	Wave Velocity
A-2/7	3302 m/sec
A-2/28	3378 m/sec
A-4/7	3251 m/sec
A-4/28	3403 m/sec

Fractures occurring in the concrete specimens for the different impactor nose shapes were generally consistent and reproducible as regards to location. This was established from preliminary testing of uninstrumented bar specimens in order to determine the threshold fracture strain necessary for single bar fracture on first wave passage. The projectile firing pressure required to achieve this single fracture for a given impactor was then used in the subsequent instrumented bar tests. Of some concern however, was the apparent narrow band

of pressure variation for which this single threshold fracture could be consistently reproduced. In order to resolve fracture position and time for the cases when multiple fracture occurred and for single fracture as well, uninstrumented as well as instrumented test bars were tested with surface electrically conducting stripes (Metex XeCoate) painted in the longitudinal direction on the bar specimens and used in connection with a specific resistor to provide a known voltage charge on the recording oscilloscope. The sequential breaking of these stripes provided a means of identifying the time of bar fracture and the fracture location. During the test program the strain gage time history was recorded on one oscilloscope while a second storage oscilloscope was used to record one of the strain gage records (usually the second gage) and the conducting stripe record. This is demonstrated in Fig. 44 , which shows a typical oscilloscope trace recording for the strain time histories of an impacted specimen and the corresponding conducting stripe record.

One of the principal points to be explored in this study of concrete fracture was further evaluation of a theory proposed in reference [16]. Fundamentally it is recognized that concrete used as a structural material is weak in tension, and this deficiency can be compensated for by adequate control of design parameters for static loading applications. However, for random dynamic loads occurring from earthquakes, explosive loadings, etc., this structural weakness becomes the potential for material removal (spall) from the structural component when the local tension exceeds the tensile ultimate strength of the material. A widely accepted design rule for such occurrances is to consider the dynamic tensile strength to be twice the static strength. This rule does not appear, however, to fit practical circumstances since the dynamic tensile stress

appears to be a function of the strain rate.

The rate dependence has led to the advancement of a dynamic fracture criterion based upon an extension of the static strain energy theory. (see ref. [16].

Analytically this dynamic fracture criterion for an axially impacted uniform bar is expressed as:

$$U_{cr} = (EA\ c/6)\ \dot{\varepsilon}^2 RT^3 = (\frac{EAC}{6})\varepsilon_{cr}{}^2 RT$$

where, U_{cr} = Critical Fracture Strain Energy

E = Elastic Modulus

A = Cross Sectional Area

C = Bar Wave Velocity

ε = Strain

RT = Rise Time to Failure of the Material

Thus, the fracture strain energy for a given material and given bar geometry is considered constant.

This cirterion has been tested for the aggregate types and material cure time cited previously, and graphically displayed in Fig.46 for the Hemispherical copper impactors for which a greater number of useable data points have been obtained. The results shown indicate that a material ranking procedure based upon the aforementioned criterion appears justified. However the test as to the justification for considering U_{cr} to be a constant with respect to strain rate or rise time appears inconclusive. In some part, this latter difficulty in interpreting the results can be attributed to the photographic scale factors used for evaluating the results as shown for example in Figs.43,44. In the present case a horizontal scale time of 20 μsec = 1cm has been used to determine the time to failure of the concrete specimen while in reference [16] a time scale of 1000 μsec = 1cm has been used. It appears that the use of the more refined time scale, introduces additional questions as to the wave transit time

and failure of the specimen, while that used in reference [16], while capturing the complete time history of the wave event may indeed gloss over details with insufficient resolution to allow proper pulse interpretation. For example, a bar transit time over a 1.0 in. (2.54 cm) interval would correspond to approximately 8 μsec representing 4 mm on our photographs and 0.08mm in those of reference [16]. Such differences in data reduction can easily lead to significant differences in quantitatively assessing the merit of the proposed criterion.

2.6 CONCLUSIONS AND RECOMMENDATIONS

The objective of these experiments was to assess the failure criterion advanced in reference [16] as a means of ranking classes of structural materials for potential spall formation under dynamic loading. Results from the tests conducted here indicate that a difference in the strain energy required to produce tensile failure in a controlled experiment over a limited range of rise times does indeed exist. However, the broader base question as to the range of applicability of U_{cr} as a measure of material spall resistance (strain rate and time to failure) remains open. This latter information if positive in nature would prove most valuable for design purposes as a direct measure of material resistance to spall formation. The current tests do indicate that impact tests, such as those reported on here, are directly useful for obtaining some specific quantitative data on material spall.

An important area of applicability of the fracture criterion to impact/blast loading situations occurs in considering the failure of such structural elements as plates and shells. The theory, as advanced in reference [16], implies that fracture may not be related to the absolute magnitude of stress and/or strain level in passing through a given station

of the material but rather reflect a cumulative damage effect. That is, considering the propagation of a pulse along the bar in the current experiments, this criterion indicates that failure occurs when a certain amount of tensile strain energy has passed through a given cross-section surface area. Additional support to this argument comes from the fact that for long pulse rise times of low amplitude, fracture of the bars occurred at comparable locations to those cases where a fast rise time, high amplitude pulse was generated. This suggests that perhaps a critical energy transmission per unit area through a potential spall surface can be related to a tensile failure/fracture criterion and to the prediction of controlled material removal. Since all the bar tests of the present program were for the same cross-sectional area, as also were all the tests of reference [16], no evidence is at hand to support the suggestion that the appropriate cirterion is energy transmission per unit area instead of total energy transmission through the spall plane, but it seems more physically reasonable. Some notion of this difference could be determined if we examine the scabbing (not penetration) of plate slabs by impact loads. For such tests the volume of material removed is not related to a planar fracture surface but rather approximately a conical surface. Considering that the critical energy flux for material removed is given as that associated with an average surface over a given time interval, then the depth of material removed for a given input energy can be related. In the case of a kinetic energy impactor the depth of material removed would be approximately proportional to the impact velocity. A check of some mimeographic data in the literature suggests the above argument may be meritorious [18].

The above remarks serve as a basis for making the following recommendations:

1. Studies of additional laboratory tests on long bar controlled and strain gaged specimens are warranted with particular attention focused on the experimental procedures and instrumentation necessary for obtaining longer strain time history records with much better resolution than is possible by using a storage oscilloscope.
2. Tests should be run not only on a few types of specimens but on a sufficient number of different material and sample types to ensure that enough data for a meaningful quantitative basis of laboratory ranking can be obtained. In particular tests with different diameter bars could distinguish between total energy versus energy per unit area as a fracture criterion.
3. Controlled tests on nonperforated concrete slabs such as the perforated one shown in Fig.47 should be conducted to test the critical strain energy theory by measuring the volume of spalled material removed for a given test versus the predicted U_{cr}.

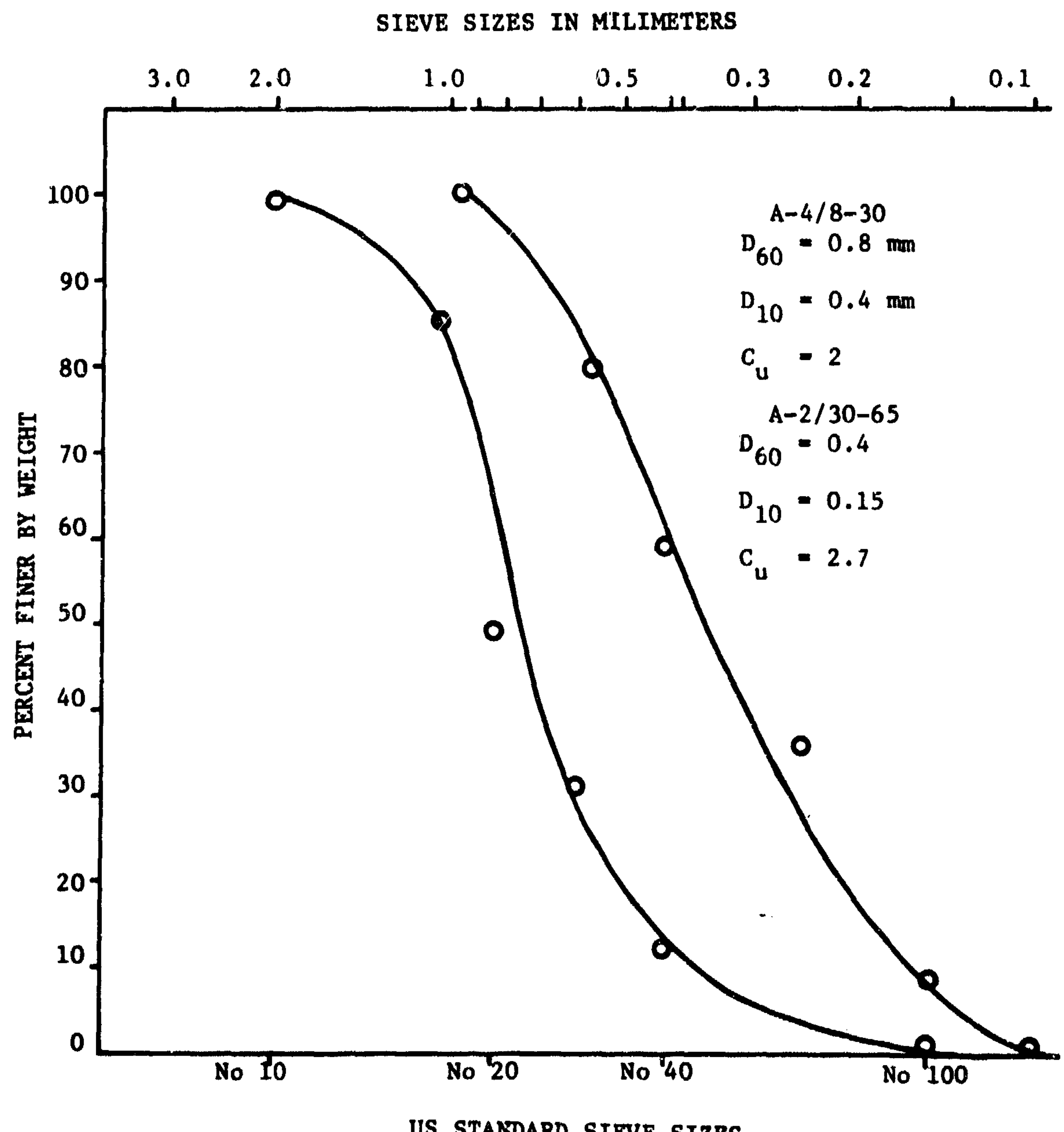


FIGURE 29. GRAIN SIZE DISTRIBUTION CURVES-EDGAR SAND 8-30,30-65

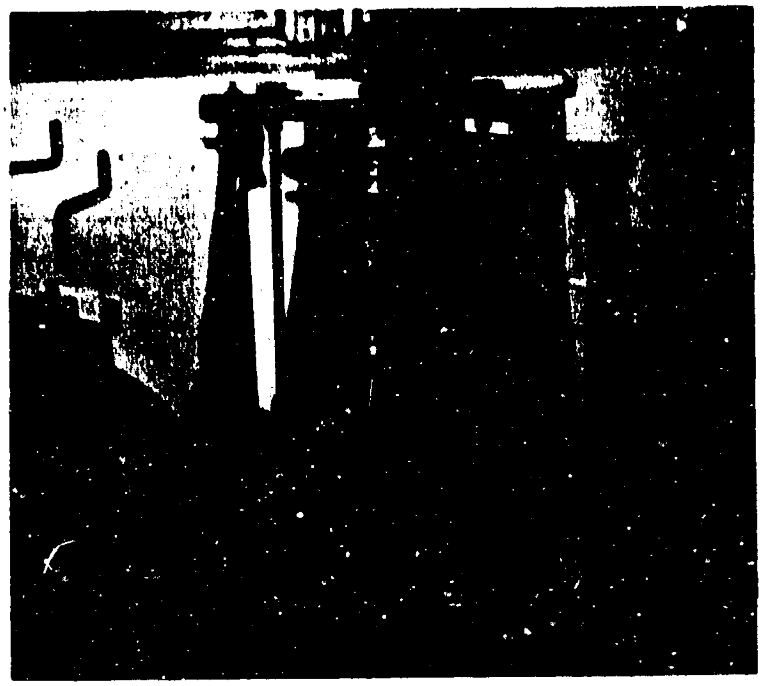


FIGURE 30. SIEVES AND SHAKER USED FOR GRAIN SIZE DISTRIBUTION.

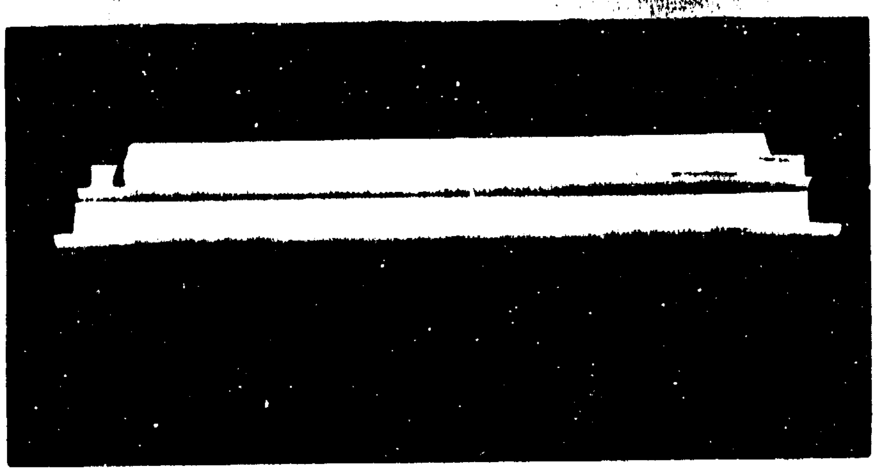


FIGURE 31. PVC MOLD FOR CASTING CONCRETE SPECIMENS.

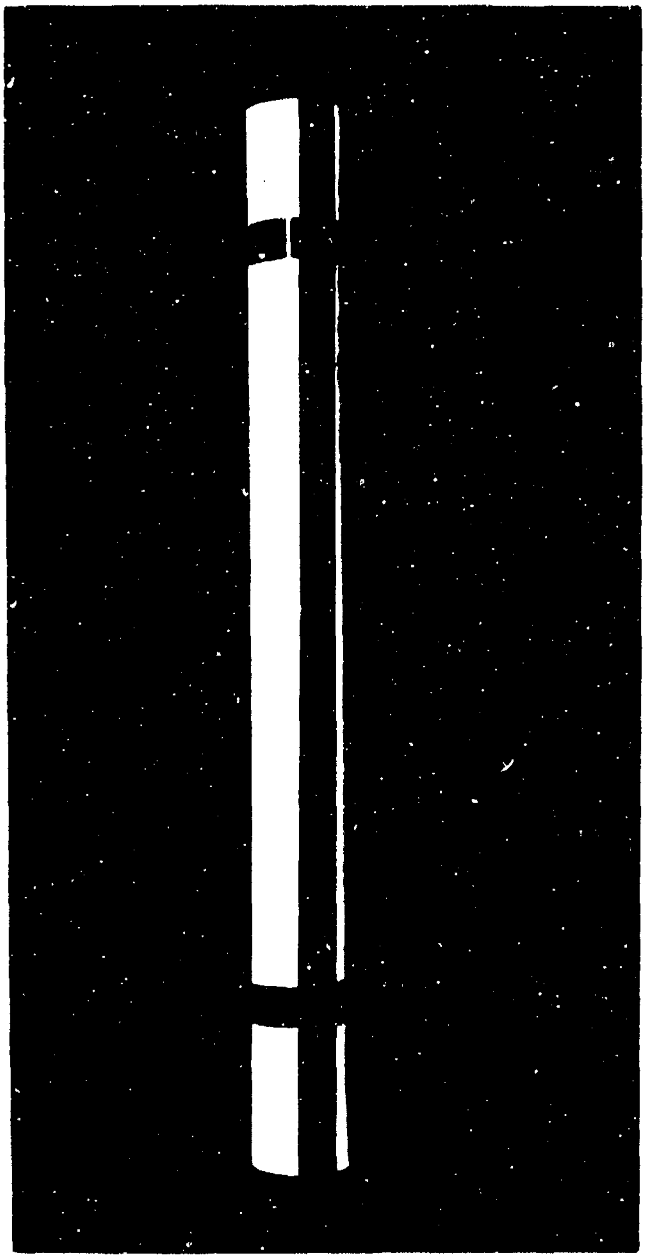


FIGURE 32 CONCRETE SPECIMEN IN MOLD ILLUSTRATING TAPING

FIGURE 33. CEMENT MIXING UNIT

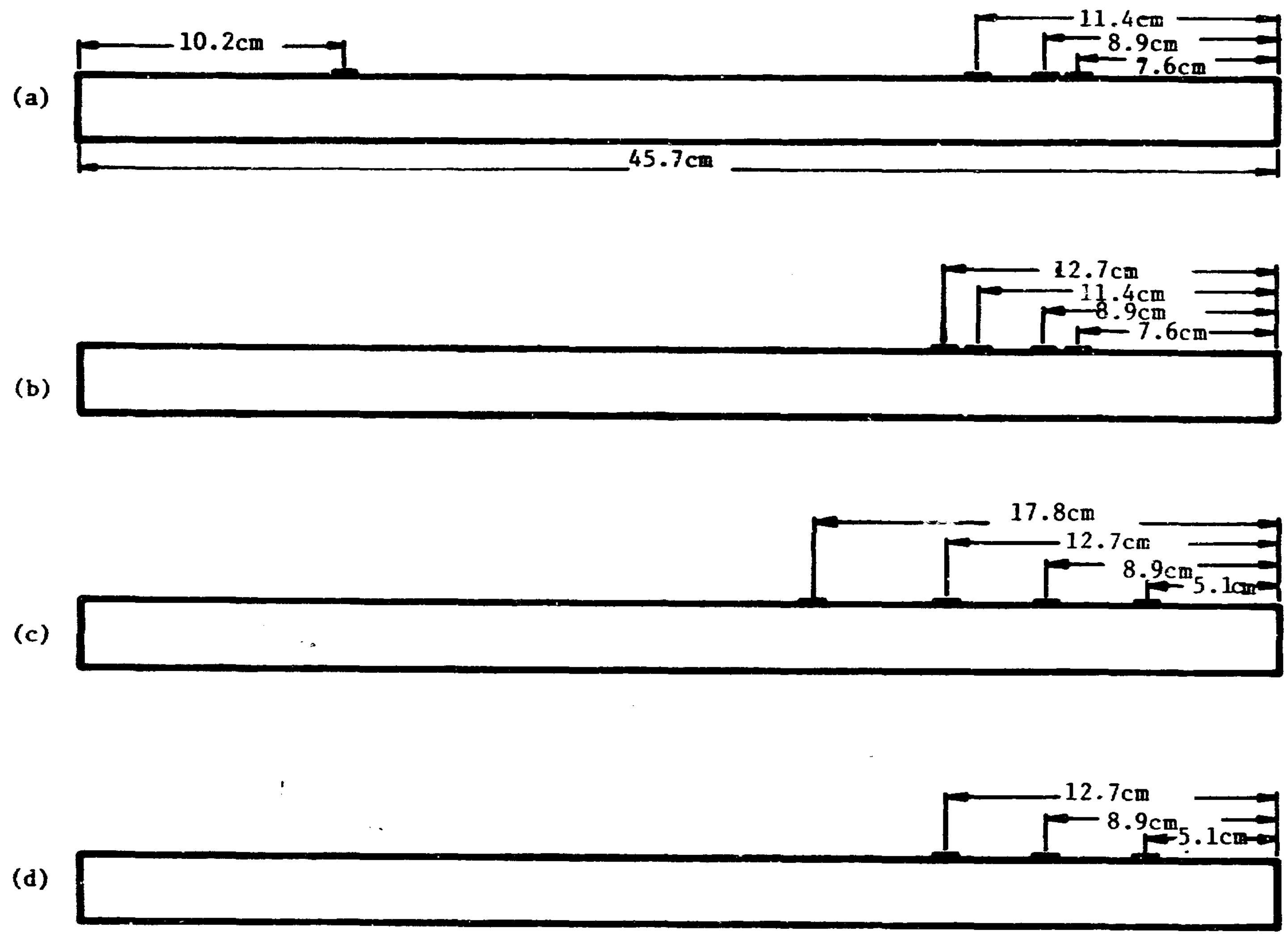


Figure 34. Strain Gage Locations for Concrete Specimens

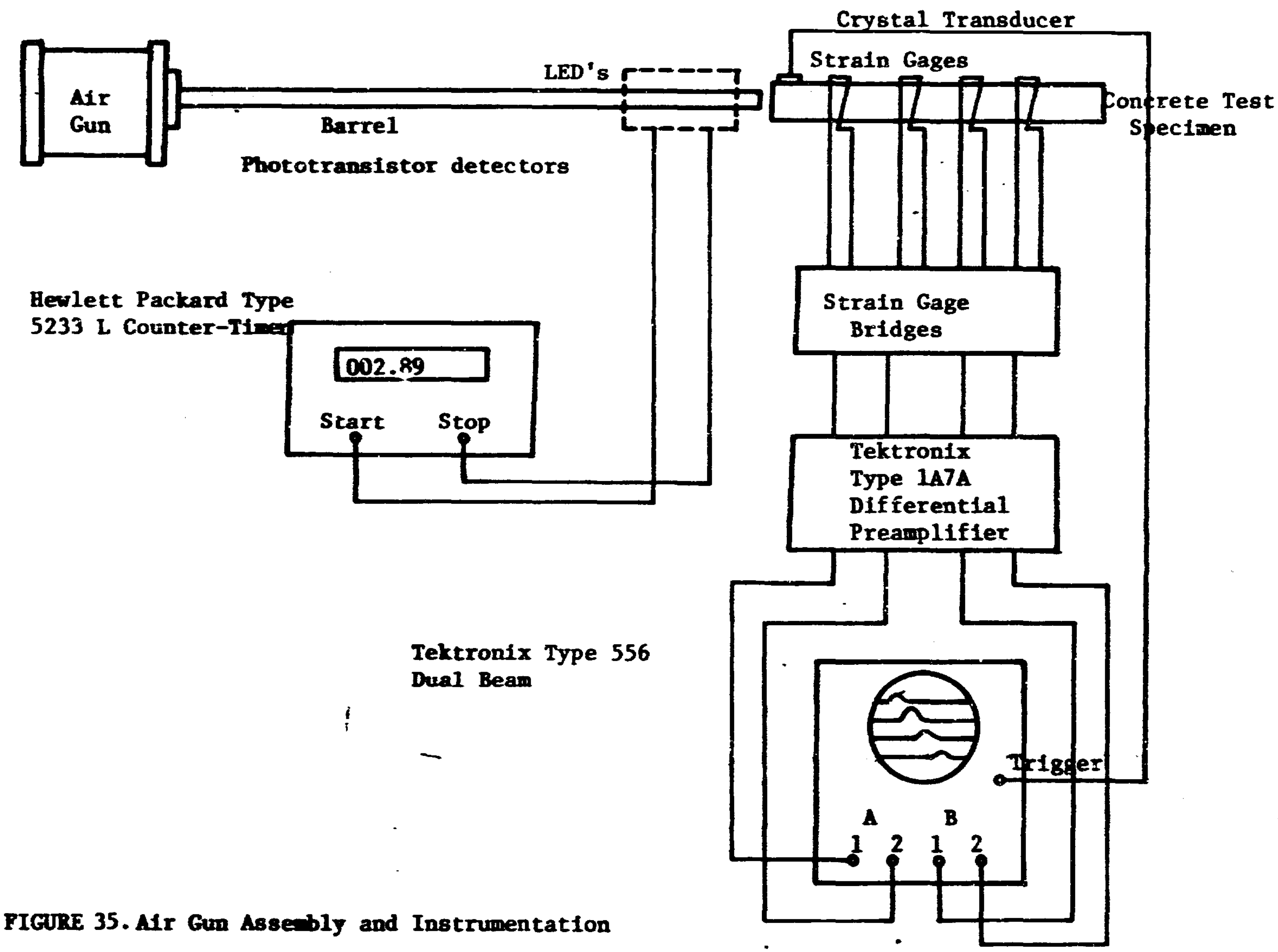


FIGURE 35. Air Gun Assembly and Instrumentation

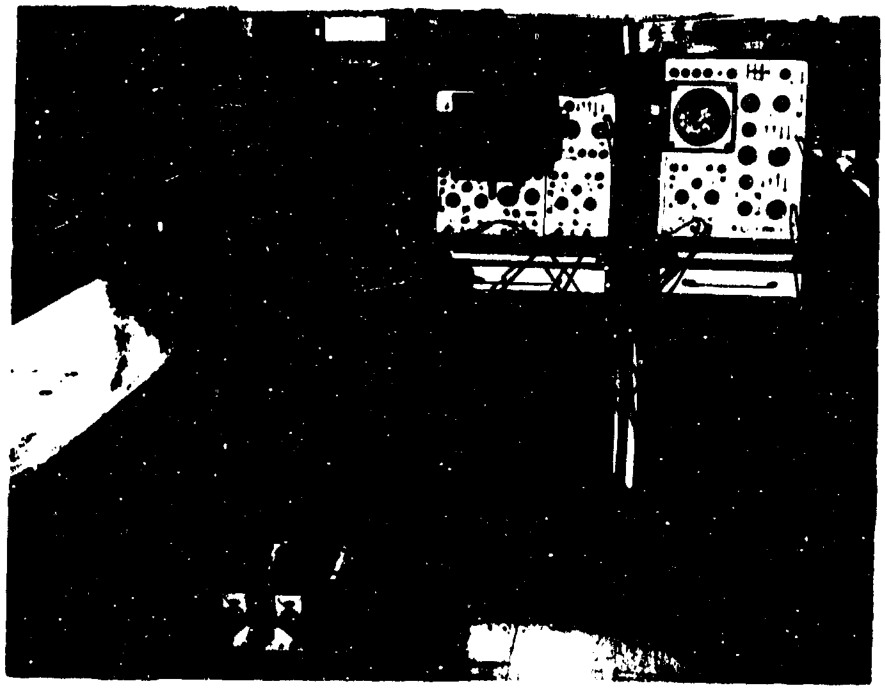


FIGURE 36. IMPACT FACILITY

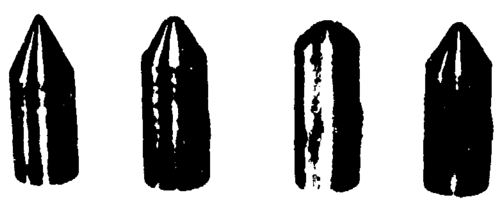


FIGURE 37. IMPACTORS USED

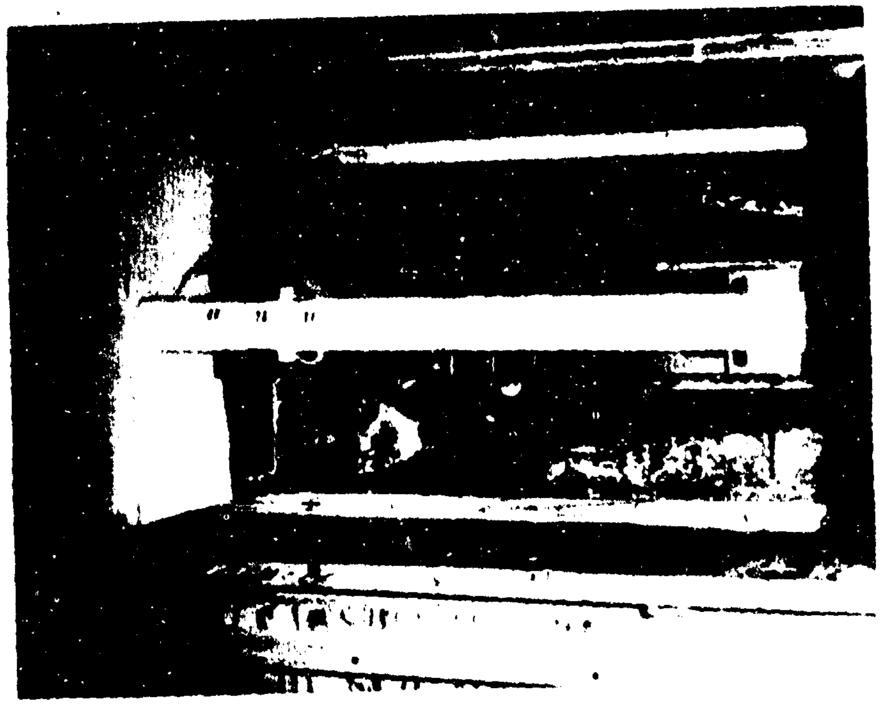


FIGURE 38. SPECIMEN SUPPORT MECHANISM

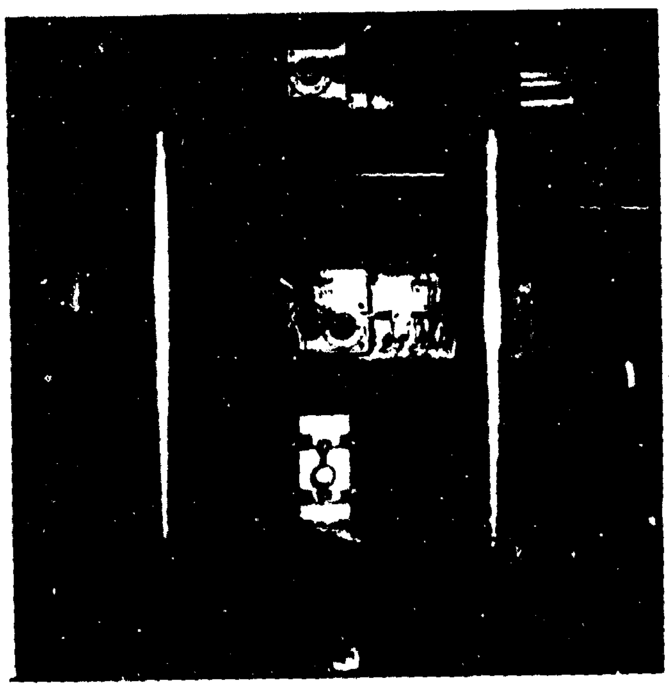


FIGURE 39. STATIC COMPRESSION TEST SET-UP FOR DETERMINING YOUNG'S MODULUS

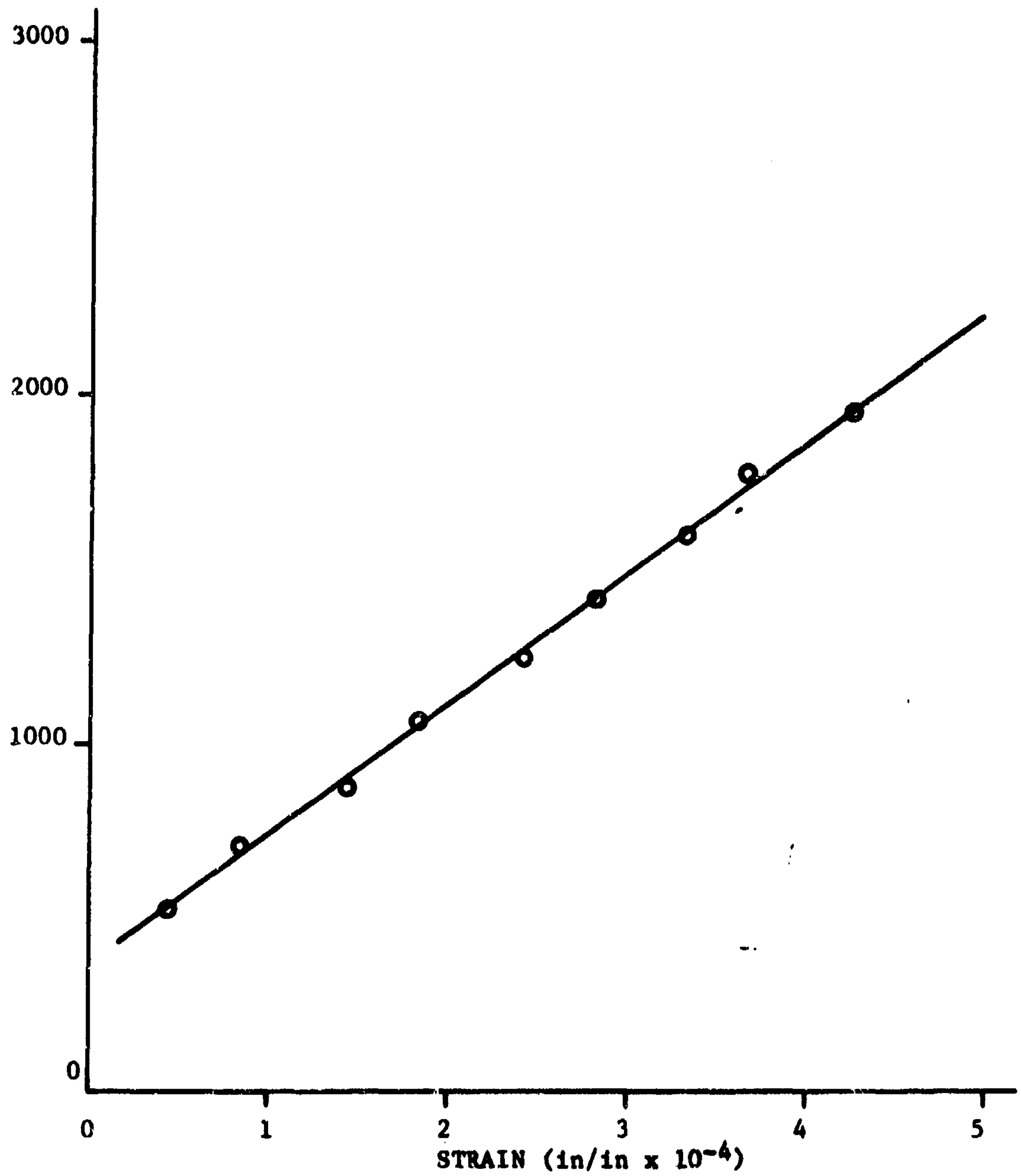


FIGURE 40. Compressive stress-strain curve

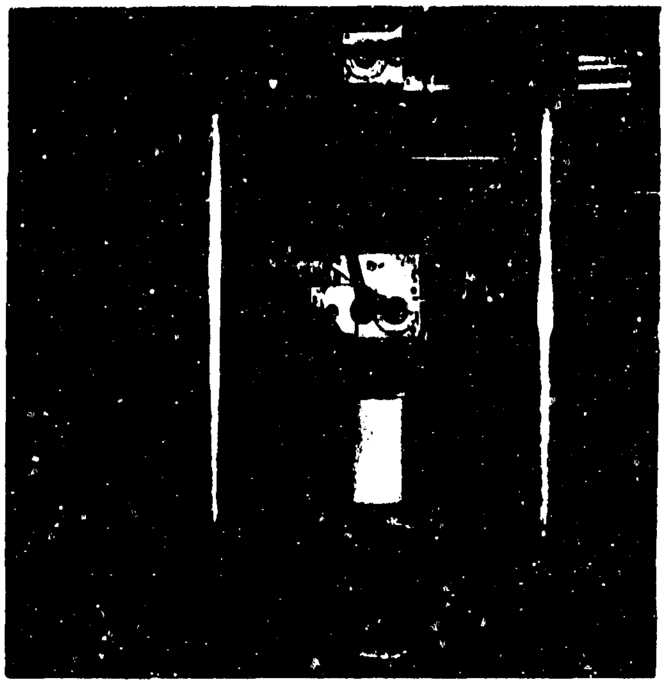


FIGURE 41. COMPRESSION TEST SET-UP FOR DETERMINING ULTIMATE STRESS

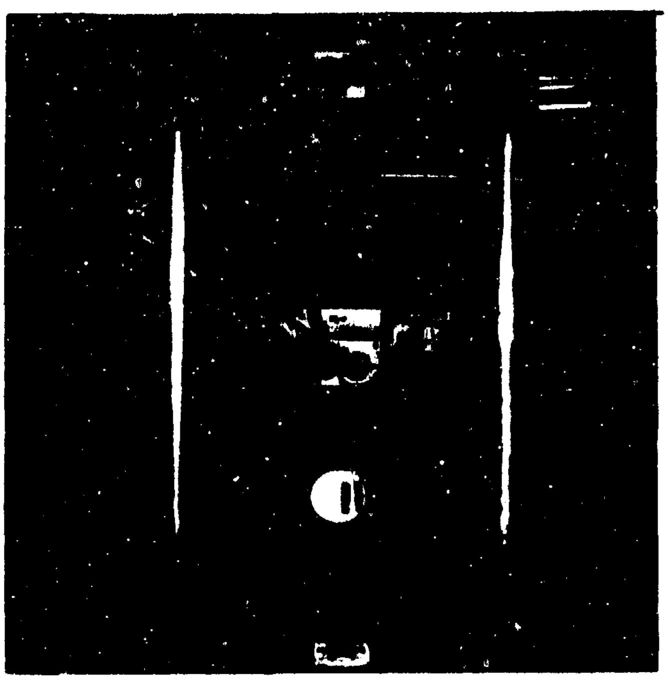
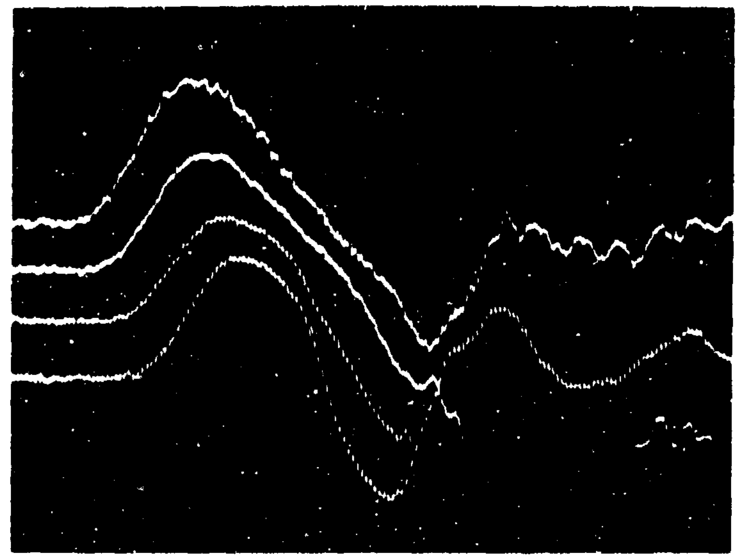
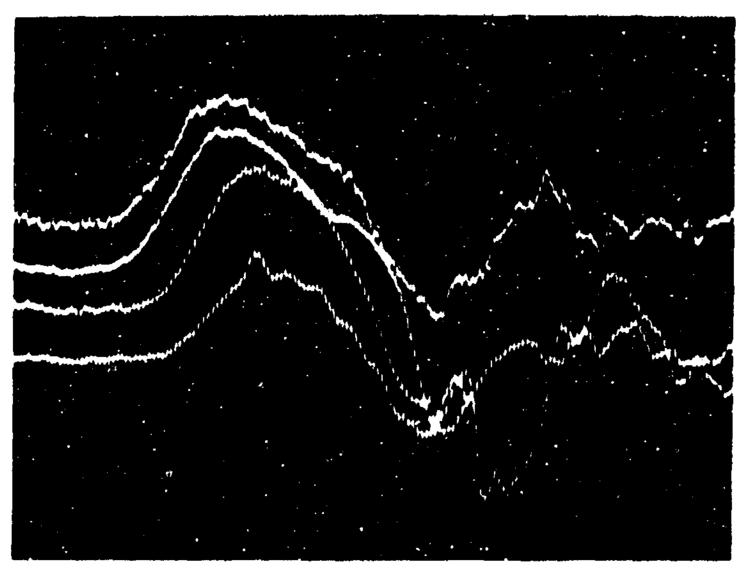


FIGURE 42. SPLIT TENSION TEST SET-UP

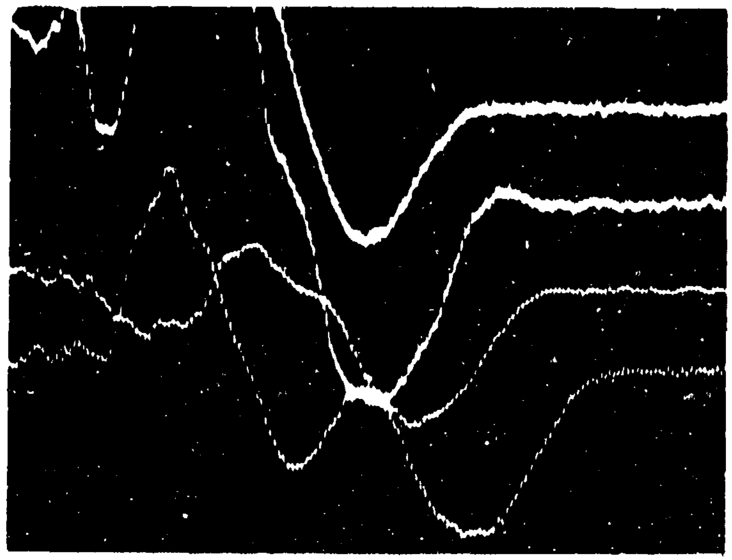


(a) Bar No. 38, A-2/28 aggregate, Impact Velocity=1488 in/sec.
Impactor: Cu with Hemispherical Nose, Oscilloscope Settings:
50mv/cm Vertical, 20msec Horizontal

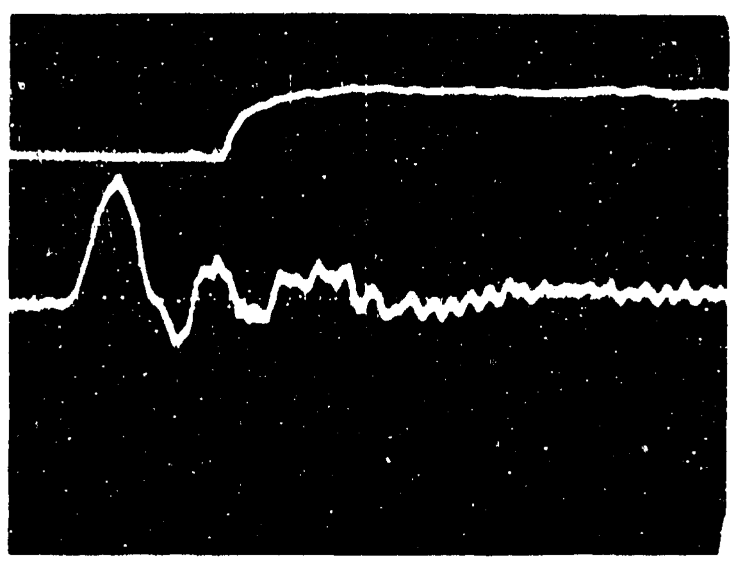


(b) Bar No. 86, A-4/7 aggregate, Impact Velocity=1479 in/sec.
Impactor: Cu with Hemispherical Nose, Oscilloscope Settings:
50mv/cm Vertical, 20msec Horizontal

FIGURES 43 a,b TYPICAL OSCILLOSCOPE STRAIN GAGE RECORDS OF IMPACTED BARS



(a) Bar No. 87, A-4/7 aggregate, Impact Velocity=1461 in/sec. Impactor: Cu with Hemispherical Nose, Oscilloscope Settings: 50mv/cm Vertical, 20usec Horizontal



(b) Top Trace: Conducting Stripe, Bottom Trace: Gage Two Oscilloscope Settings: 50mv/cm Vertical, 50msec Horizontal

FIGURES 44. TYPICAL OSCILLOGRAPH STRAIN GAGE RECORDS OF AN IMPACTED BAR WITH CONDUCTING STRIPE

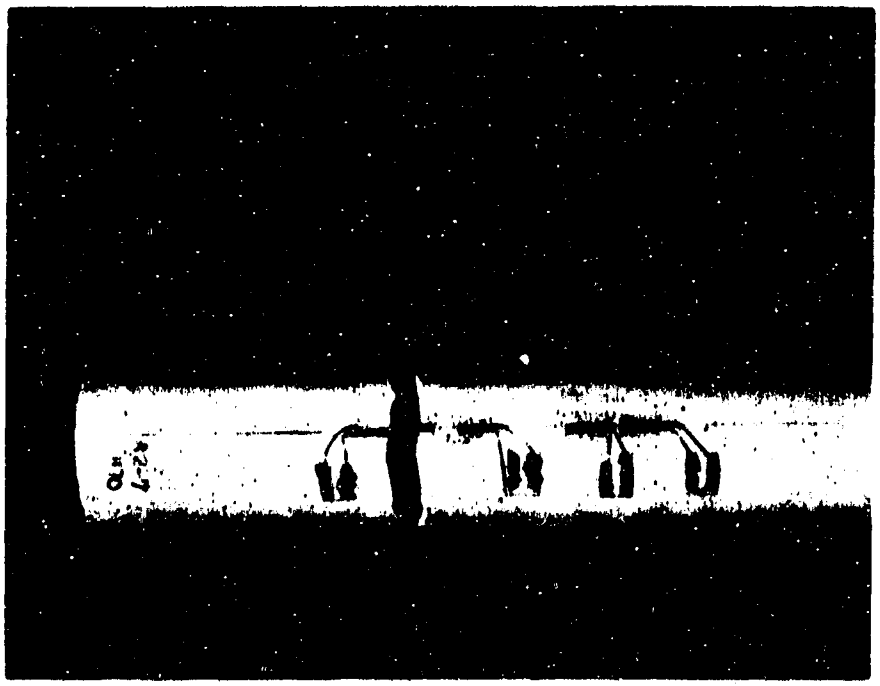


FIGURE 45. TYPICAL FRACTURE OBTAINED BETWEEN GAGES OF INSTRUMENTED CONCRETE SPECIMEN, BAR #70, A-2/7 AGGREGATE

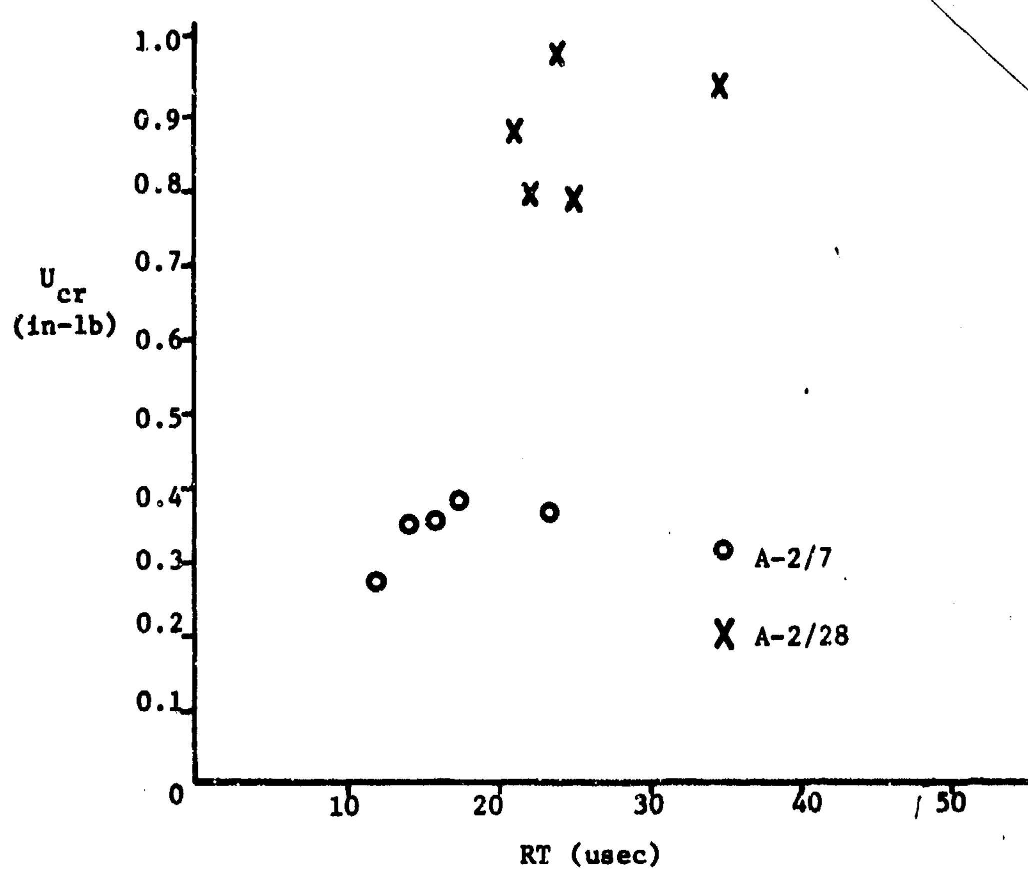


FIGURE 46 CRITICAL STRAIN ENERGY vs RISE TIME TO FRACTURE

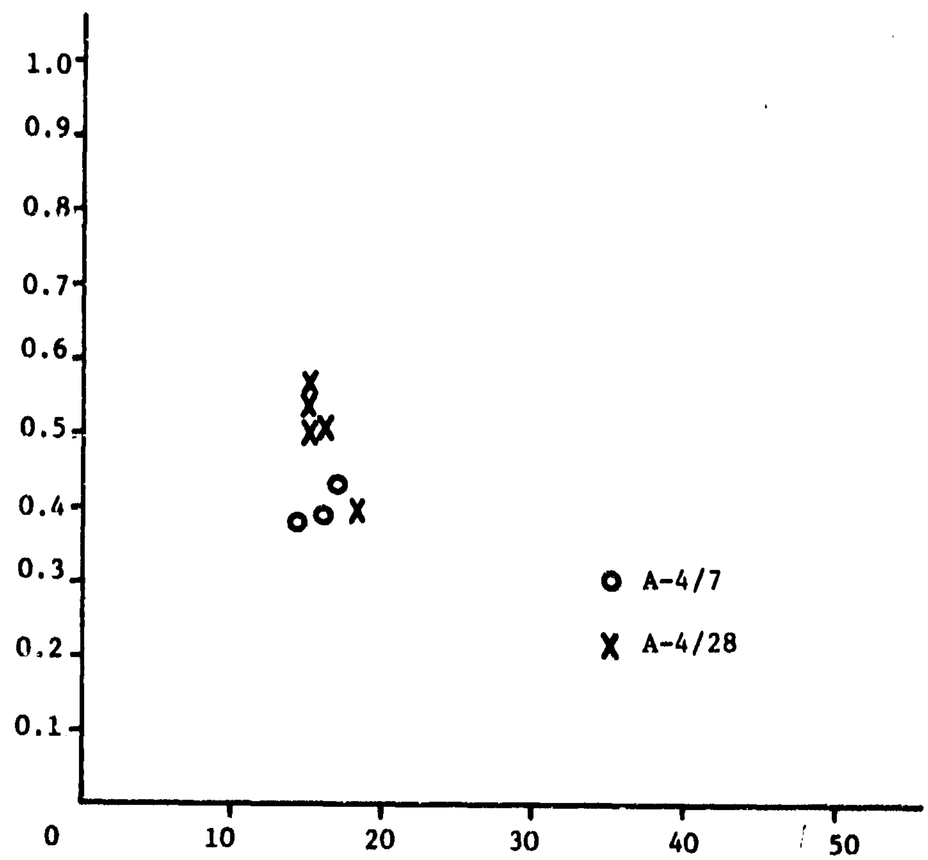


Figure 46b. CRITICAL STRAIN ENERGY vs RISE TIME TO FRACTURE

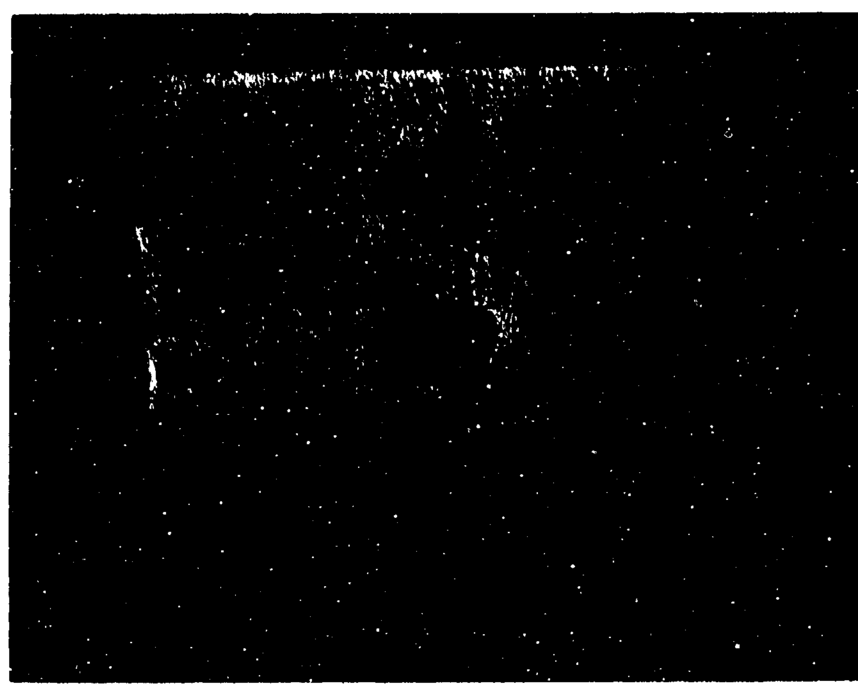


FIGURE 47 TYPICAL FRACTURE OF PENETRATED CONCRETE PLATE (6"x6"x½")

SECTION III

STUDIES ON THE DYNAMIC STRESS CHARACTERIZATION OF PENETRATOR NOSE SHAPES

3.1 INTRODUCTION

During the impact of a kinetic energy penetrator against another finite sized body, a stress wave is developed in each body. These stress waves progress away from the impact point at magnitudes and velocities dependent on the physical and mechanical properties of each material as well as the impact velocity.

For higher impact velocities the magnitude of the stress associated with the shock or stress wave may still be of sufficient strength to cause failure at sites far removed from the impact point. The transfer of a high stress magnitude through an impacting vehicle is very much dependent upon the type and nose shape of the impactor. A nose shape which may be suitable for one target may not be satisfactory for another or for some combination of material targets. While it is not feasible to determine the exact magnitude of the transmitted pulse due to difference in material and impacted surface conditions, it is possible to compare peak stress magnitudes with respect to a reference impactor.

To facilitate such studies the Hopkinson pressure bar has been used for examining the pulse stress transmission through fixed length specimens of varying nose shapes. Included in these studies is a brief examination of the effect of concrete materials on the interactive stress transmission through some typical penetrator shapes.

3.2 EXPERIMENTAL PROGRAM

For investigating the stress transmission through test specimens of various shapes, the Hopkinson Pressure Bar shown schematically in Figure 48 has been used. Tests involving

concrete were accomplished by simply inserting a thin concrete wafer between the incident bar and the metal specimen. This position is noted in exploded view A of Figure 48 . An extensive description of the pressure bar operation and experimental data on classes of materials is contained for example in references [19,20].

Specimens used for the current test program were fabricated from annealed AISI-WI drill rod. This is the same kind of steel being used in current full scale soil impact test specimens at Eglin AFB. A Rockwell Hardness test (C scale) was made on the material in the as received state. An average value of 25 was obtained which corresponds to a nominal ultimate tensile strength of 125,000 psi (862.1MPa). A further check on the material properties was made from compression tests run on a 20,000 pound Instron machine using 1/2 in (1.27 cm) diameter by 1/4 in long (.635 and 1.27 cm) specimens run at a cross head speed of .02 in/min (.51cm/min). Results from these tests show a reproducible compressive yield stress of 65,000 psi (448.3 MPa).

The drill rod material was subsequently used to fabricate various nose shape specimens indicated in the accompanying table and shown both before and after testing in Figures 49 and 50 , respectively.

All Hopkinson pressure bar tests were run at a bar draw back distance of three inches which corresponds to a striker bar velocity of 230 in/sec (5.84 m/sec). The selection of this impact velocity was made based upon prior studies on softer materials such as aluminum and copper based metals and the static steel strength properties reported on here. From the results obtained for this study it would be advantageous to conduct additional tests at higher stress levels (impact velocities) and with various grades of steel to ensure that both the elastic and plastic deformation regimes would be

covered during the test program.

Since relatively high strength steel and rather sharp ended specimens were used in these experiments, the ends of the transmitter and receiver bars were protected by use of thin wafers, nominally 0.065 in (0.17 cm) thick, fabricated from AISI-WI drill rod (1095 steel) and heat treated for maximum strength (see view A of Figure 48). The heat-treated wafers were tested using the Rockwell hardness tester and had a nominal hardness of 57 on the C scale. This corresponds to an ultimate tensile strength of approximately 300,000 psi (2069 MPa).

Generally three specimens of each geometrical shape were tested and the average of the three tests reported in Table The exception to this procedure was for the ogive/concrete specimens. The maximum stress ratio reported in Table XV is a ratio of the maximum stress determined from calibration (constant for all tests) to the maximum stress measured in the transmitter bar. During the initial phases of this test sequence, the hardened steel wafers shattered and portions of the wafers were then used in completing the tests. For these latter tests, only one or two tests were made for each specimen type. Representative Hopkinson Bar stress-strain curves tested for the blunt and ogive specimens are shown in Figures 51 and 52 . Addition of concrete wafers in series with these two types of specimens modifies the stress strain curve as shown in Figures 53 and 54 .

3.3 DISCUSSION OF RESULTS

The data obtained from these tests has been reduced and compared on the basis of peak stress transmission through the impactor. This stress ratio may be considered as a relative figure of merit for nose shape performance. These tests were run to simulate hard target impact between acoustically matched

TABLE XV
HOPKINSON BAR SPECIMFNS TESTED

Specimen Shape (all dimensions in cm)	Maximum Stress Ratio	Material Type
Blunt Nose		
1.27 Dia x 2.54 long	1.0	AISI-W1(1095) Steel
1.27 Dia x 1.27 long	0.98	AISI-W1
1.27 Dia x 0.64 long	0.95	AISI-W1
0.95 Dia x 2.54 long	1.0	AISI-W1
Step Tier		
1.27 Dia(.25 step) x 1.27 long	0.88	AISI-W1
1.27 Dia(.64 step) x 2.54 long	0.78	AISI-W1
90° Cone		
1.27 Dia x 2.54 long	0.31	AISI-W1
0.95 Dia x 2.54 long	0.31	AISI-W1
(90° Cone)/Ogive		
1.27 Dia x 2.54 long	0.28	AISI-W1
45° Cone		
1.27 Dia x 2.54 long	0.08	AISI-W1
Concrete		
1.91 Dia x .64 long	0.39	A-4 (see section II for concrete type)
1.91 Dia x 1.27 long	0.46	A-4
Blunt Nose/Concrete		
1.27 Dia x 2.54 long 1.91 Dia x .64 long	0.44	AISI-W1 A-4
1.27 Dia x 2.54 long 1.91 Dia x 1.27 long	0.46	AISI-W1 A-4
Ogive/Concrete		
1.27 Dia x 2.54 long 1.91 Dia x .64 long	0.036	AISI-W1 A-4
1.27 Dia x 2.54 long 1.91 Dia x 1.27 long	0.054	AISI-W1 A-4

specimens and this information is shown in Table XV. It is observed that for the impact velocity selected an elastic response for the blunt nosed cylinder has been obtained. Tests run on such impactors with different lengths and diameters show relatively little influence of geometrical scaling effects for such impactors. As a secondary blunt nose (stepped tier) shape is added, however, the peak stress transmitted to the after body of the impactor is reduced. This is further evidenced by the tests on pointed nose shapes in which plastic deformation occurs.

Much of this data is as would be expected for acoustically matched impacts of hard bodies against hard targets at low impact velocities. It would be of considerable interest to examine the peak stress transmission and the work associated in deforming such vehicle nose shapes over a wider range of impact velocities or stress wave magnitudes to compare elastic/plastic effects.

In addition to the load transmissions between strictly hard targets, some tests using selected steel penetrator nose shapes with a buffer material have been run. The buffer material for these tests was concrete of the A-4 aggregate type, nominal static compressive stress of 8100 psi (55.4 MPa) as described in Section 2. (Figure 55). Dynamic tests on 3/4 in (.95 cm) diameter by 1/4 in (.65 cm) and 1/2 in (1.27 cm) long concrete specimens have been run, with a nominal increase of approximately 15 percent noted in the compressive failure stress. The thinner sized specimens were observed to have a stress closer to the static failure stress, and this can be attributed to the difficulty of controlling parallel end surfaces leading to an edge effect. This is further demonstrated from the results obtained when blunt nosed specimens are used in conjunction with the concrete disc specimens and stress transmission levels

comparable to the concrete itself are obtained. For these latter tests an apparent false nose of crushed concrete has been formed on the blunt nosed penetrators, with complete comminution of the concrete observed. For the case of ogive penetrators used against two thicknesses of concrete discs, a much lower stress transmission is noted than with either of the specimen types considered separately. This is suggestive of some multiplicative or numerically cumulative interactive effect taking place. The failure of the concrete in this case is purely a radial splitting into three arc segments of approximately 120 degrees. A comparison of the two types of failures observed for the blunt nose and ogive specimens tested against the concrete wafers are shown in Figs. 56, 57.

For impact of a given kind of penetrator the transmitted stress is proportional to the impact velocity and for kinetic energy penetrators the energy available for penetration is proportional to the square of the velocity. This leads to the assumption that the square of the transmitted stress level may be an indicator of the energy transmitted to the rear portion of the specimen; thus one minus the square of the stress ratio is a measure of the percentage of energy absorbed by the nose section. Verification of this could be determined by using the area under the dynamic stress strain curve, however additional tests at various incident stress levels would be required before any definite conclusion could be made. This area of investigation appears to warrant further study to examine load transfer between various classes of materials, interactive fracture mechanisms, and quantification of energy absorption in penetrator/buffer materials.

3.4 CONCLUSIONS AND RECOMMENDATIONS

The objective of this set of experiments was to determine if there was an effect of nose shape on the ratio

of transmitted stress to incident stress for various nose shapes. This objective was accomplished and it may be concluded that a definite effect does exist and is related to the sharpness of the initial impact point of the specimen. This conclusion is based on a set of experiments where the blunt nose specimen stress level was in the elastic range. However, the results point up the fact the split Hopkinson bar can be used to rank types of penetrators in terms of penetration effectiveness and quantify certain design parameters.

On the basis of this conclusion the following tests are recommended.

1. Test all nose shapes using both elastic and plastic stress levels for the reference blunt end specimen.
2. Generate dynamic stress-strain curves and determine the energy of deformation using the area under stress-strain curve. Compare this with the one minus transmitted maximum stress squared term.
3. Instrument specimens in No.1 above and determine actual strain levels and compare to average values obtained in No. 2 above.
4. Test all nose shapes using various buffer materials.
5. Test samples at various angles to simulate angle of attack impact.

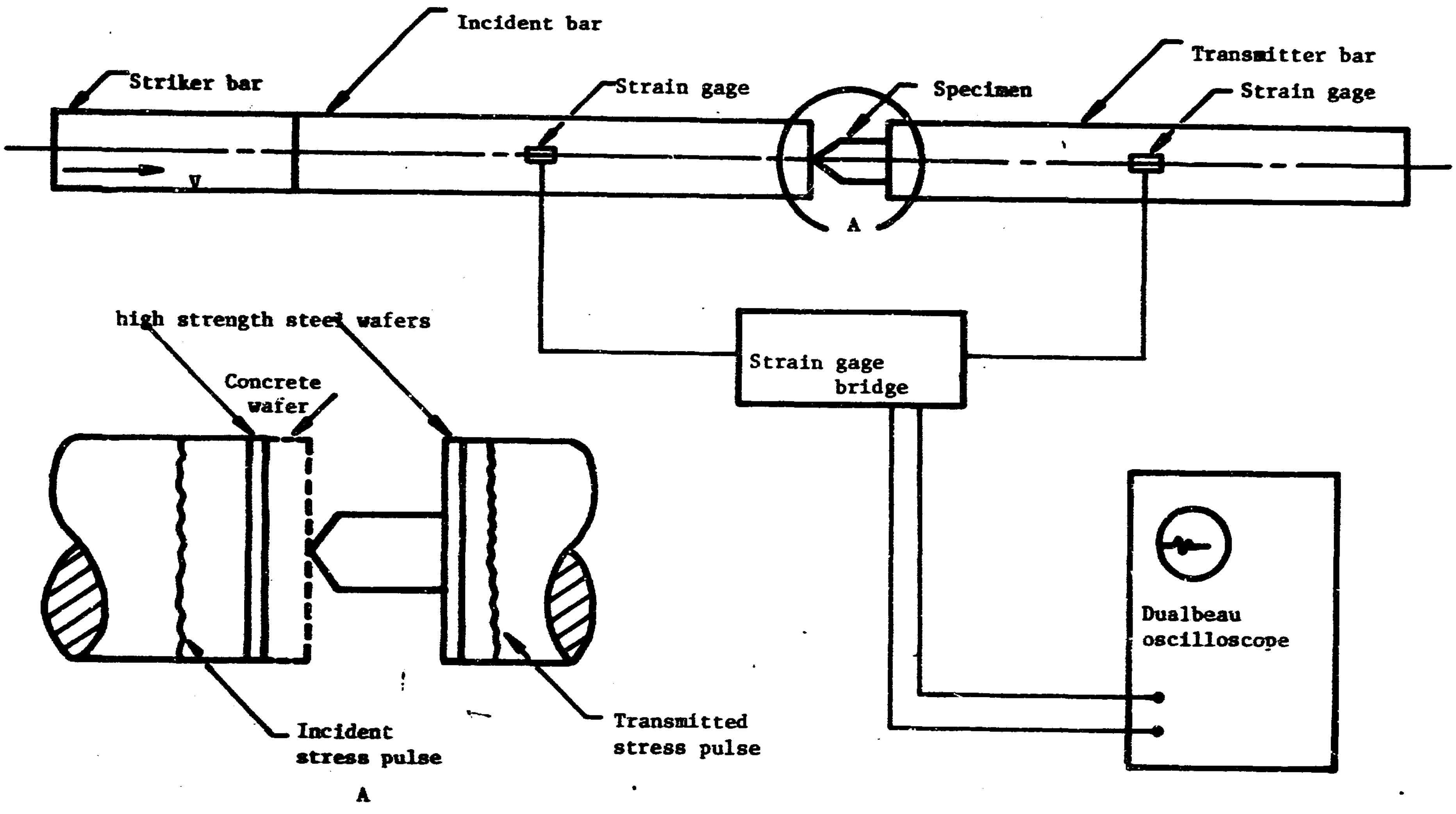


FIGURE 48. HOPKINSON BAR ARRANGEMENT

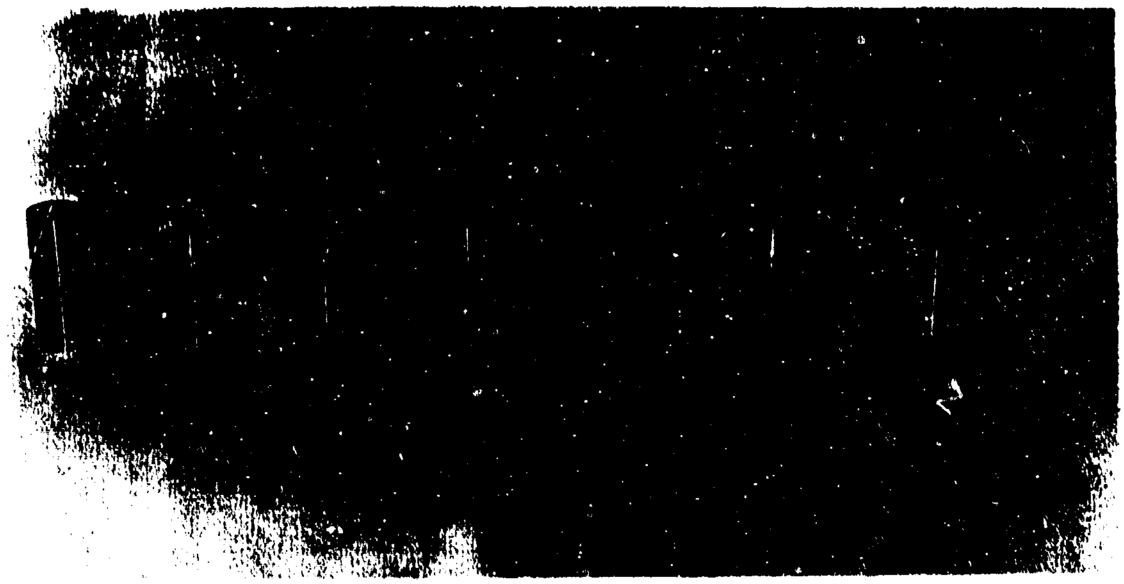


FIGURE 49. STEEL TEST SPECIMENS SHOWN PRIOR TO TESTING.

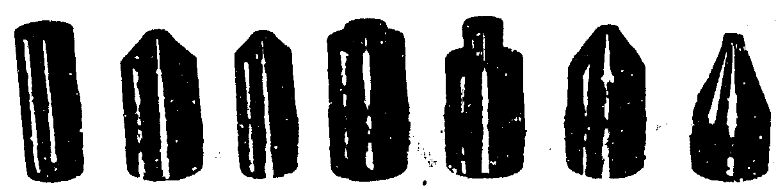


FIGURE 50. POST-TEST PHOTOGRAPH OF DEFORMED STEEL SPECIMENS.

FIGURE 51. STRESS-STRAIN CURVE OF STEEL BLUNT ENDED 1.27 cm DIAMETER x 2.54 cm LONG STEEL SPECIMEN. STRAIGHT LINE IS TYPICAL OF ELASTIC CURVE

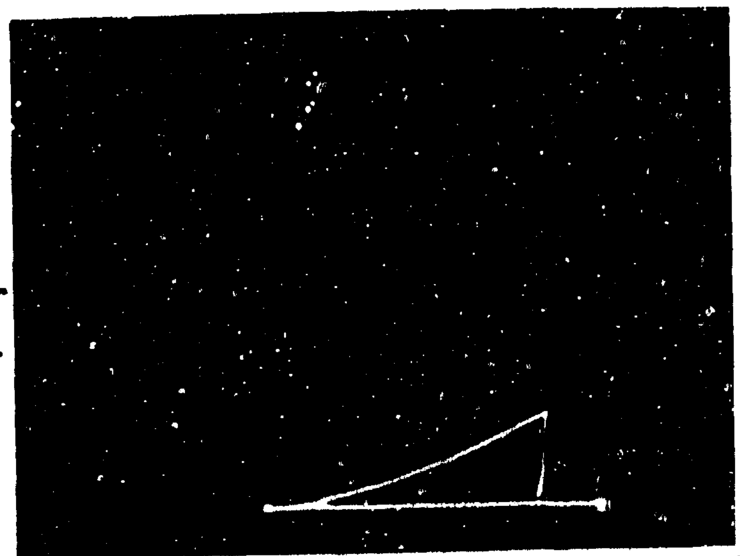
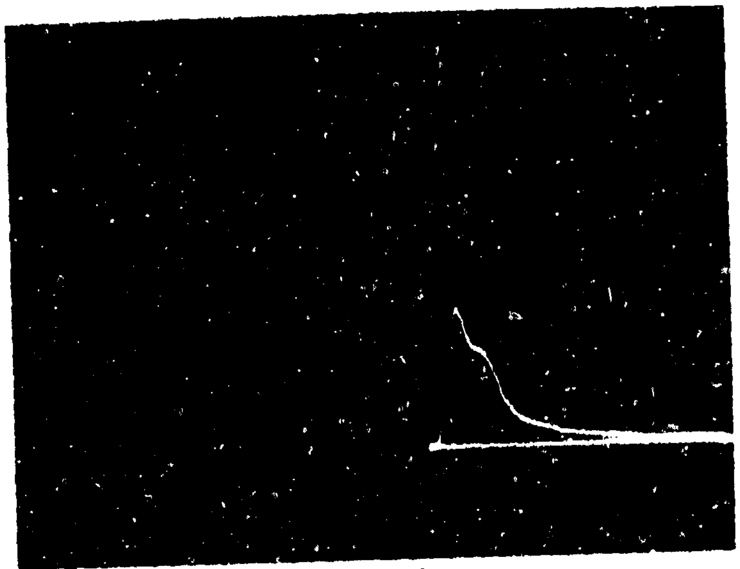


FIGURE 52. STRESS-STRAIN CURVE OF 1.27 cm DIAMETER x 2.54 cm LONG STEEL OGIVE SPECIMEN

σ



ε

FIGURE 53. STRESS-STRAIN CURVE OF 1.27 cm DIAMETER x 2.54 cm LONG STEEL BLUNT ENDED SPECIMEN IN SERIES WITH 1.91 cm DIAMETER x .64 cm THICK CONCRETE WAFER.

σ

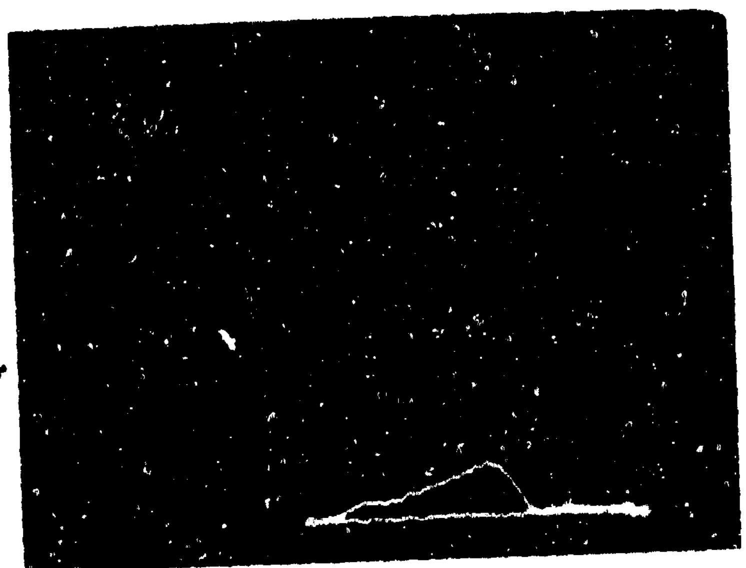


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FIGURE 54. STRESS-STRAIN CURVE OF 1.27 cm DIAMETER x 2.54 cm LONG STEEL OGIVE IN SERIES WITH 1.91 cm DIAMETER x .64 cm THICK CONCRETE WAFER.

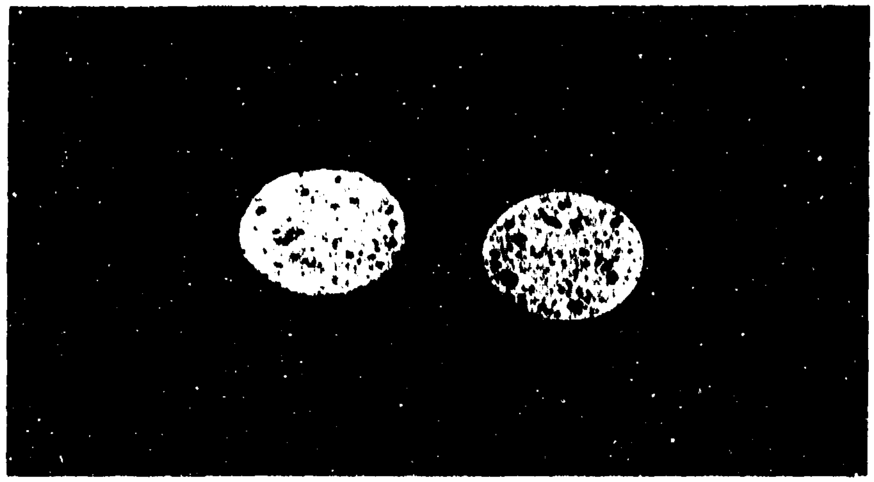

FIGURE 55. CONCRETE BUFFER MATERIALS TESTED, A-4 AGGREGATE/28 DAY CURE

FIGURE 56. TYPICAL CONCRETE FRACTURE FOR FLAT NOSED SPECIMEN

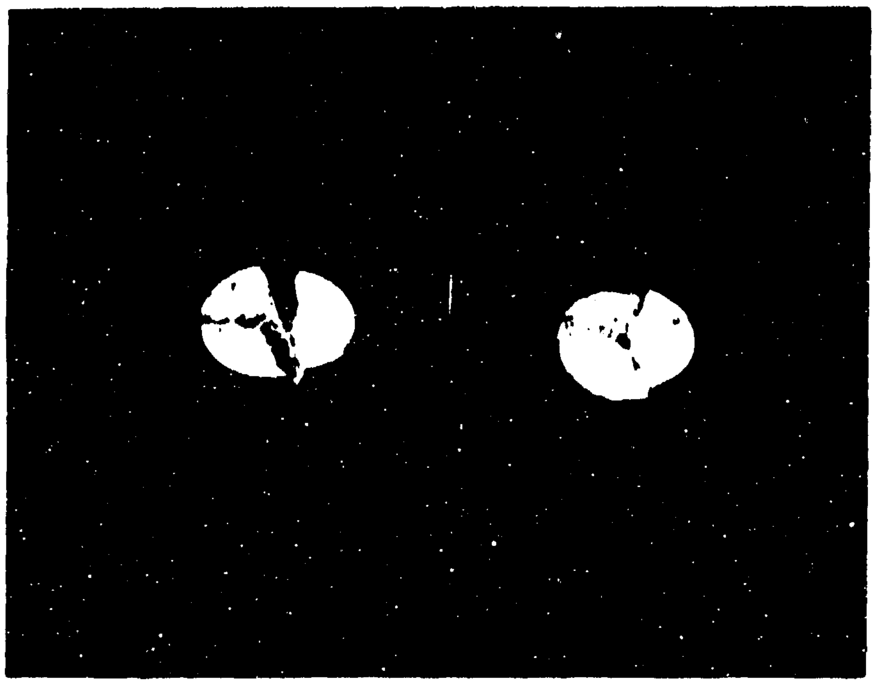

FIGURE 57. TYPICAL CONCRETE FRACTURE FOR OGIVE SPECIMEN

SECTION IV

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APPENDIX A - DATA FROM EGLIN PENETRATION EXPERIMENTS*

SHOT 2 (10-11-76 ,NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=177. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.4969 KG LENGTH=0.206 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00056	0.00167	0.00374	0.00630	0.01047	0.01693	*******
NOSE POSITION (M)..							
X-COMP.	0.10176	0.10086	0.10067	0.08804	0.05819	*******	*******
Y-COMP.	0.14878	0.39211	0.76158	1.07294	1.43784	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.10405	0.11843	0.11243	0.08390	*******	*******
Y-COMP.	*******	0.17207	0.56772	0.92205	1.31686	*******	*******
YAW ANGLE (DEG)....	-0.3	-0.9	-3.1	-4.4	-5.9	0.0	0.0
C.G. POSITION (M)..							
X-COMP.	0.10284	0.10246	0.10955	0.10024	0.07105	*******	*******
Y-COMP.	0.04579	0.28209	0.66465	0.99749	1.37735	*******	*******

COEF. OF CUBIC POLYNOMIAL: -0.93470-01 0.2531D 03 -0.1552D 05 0.4551D 06

FROM PONC. Y C.G. =	0.03888	0.29070	0.66465	1.00614	1.37501	1.64280	********
ERROR (M).......	-0.00690	0.00861	0.0	0.00865	-0.00234	********	********
C.G. VY (M/S) =	248.	208.	156.	113.	67.	18.	

AT T=0.C. C.G. VY= 273. ; WHEN VY=0.0, T= 0.01970 AND Y= 1.66790

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.8700 ER=0.02339 EM= 0.0328 CD= 1.7895

ALL STATIONS A= 6499.2 B= 0.5690 ER=0.00711 EM= 0.0086

*listed in order by shot numbers, omitting 10 shots for which transient records were obtained at fewer than two stations. Description of tabulated experimental data is given in Section 1.3.2, and explanation of the tabulated results of classical analysis is given in Section 1.4.

```
                    SHOT    3 (10 11-76 ,NO. 3)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=222. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.4969 KG  LENGTH=0.206 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00060   0.00171   0.00398   0.00685   0.01205   0.02143   *******

NOSE POSITION (M)..
   X-COMP.          0.13157   0.12991   *******   *******   *******   0.09163   *******
   Y-COMP.          0.15929   0.40836   *******   *******   *******   1.61033   *******

TAIL POSITION (M)..
   X COMP.          *******   0.13255   0.14665   0.15325   0.13546   *******   0.02390
   Y-COMP.          *******   0.18914   0.62176   0.95313   1.38091   *******   2.06913

YAW ANGLE (DEG)....   -0.3      -0.5      -2.3      -4.0      -6.0      -5.5      -5.4

C.G. POSITION (M)..
   X-COMP.          0.13265   0.13123   0.13839   0.13909   0.11405   0.11128   0.00478
   Y-COMP.          0.05630   0.29875   0.72443   1.05515   1.48166   1.50922   2.17034

COEF. OF CUBIC POLYNOMIAL:    -0.7010D-01    0.2319D 03   -0.1020D 05    0.1315D 06

FROM PONC. Y C.G. = 0.04232   0.30548   0.72443   1.09850   1.48380   1.50814 ********
   ERROR (M)...... -0.01397   0.00673   0.0       0.04335   0.00214  -0.00108 ********
   C.G. VY (M/S)  =   256.      217.      157.      107.       45.     *****
   AT T=0.0.  C.G. VY= 266.      :  WHEN  VY=0.0.  T= 0.01703  AND  Y= 1.59468

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0   B=  0.8482  ER=0.01898  EM=-0.0255  CD=  1.7446
   STATIONS 2-5    A=      0.0   B=  1.0809  ER=0.30761  EM=-0.0106  CD=  2.2232
   STATIONS 3-6    A=      0.0   B=  0.8909  ER=0.23163  EM=-0.2576  CD=  1.8324
   ALL STATIONS    A=      0.0   B=  1.3129  ER=0.20187  EM= 0.3773  CD=  2.7003

   STATIONS 1-4    A= 24218.7   B=  0.0037  ER=0.00785  EM=-0.0118
   STATIONS 2-5    A=      0.0   B=  1.0807  ER=0.00761  EM=-0.0105
   STATIONS 3-6    A=      0.0   B=  1.0807  ER=0.25724  EM=-0.4456
   ALL STATIONS    A=  8798.9   B=  0.5106  ER=0.02062  EM= 0.0434
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                          SHOT    4 (11-11-76 ,NO. 1)

        DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=309. M/S
        SOLID FLAT NOSE PROJECTILE : MASS=0.4965 KG  LENGTH=0.206 M

X-RAY STATION......    NO.1     NC.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECCNDS)..... 0.00059  0.00167  0.00399  0.00686  0.01203  0.02144  *******

NOSE POSITION (M)..
    X-CCMP.         0.12398  0.12209  *******  0.07255  -.00667  *******  *******
    Y-COMP.         0.15325  0.78647  *******  1.55290  2.00419  *******  *******

TAIL FCSITICN (M)..
    X-CCMP.         *******  0.14745  0.14577  *******  0.04881  *******  *******
    Y-COMP.         *******  0.57820  0.95284  *******  1.81685  *******  *******

YAW ANGLE (DEG)....   -0.1     -7.5     -4.9     -7.4    -18.1      0.0      0.0

C.G. POSITICN (M)..
    X-COMP.         0.12434  0.13477  0.12824  0.09886  0.02107  *******  *******
    Y-COMP.         0.05025  0.68234  1.05434  1.45332  1.91052  *******  *******

COEF. OF CUBIC POLYNCMIAL:   -0.1910D 00    0.5529D 03   -0.6624D 05   0.2895D 07

FRCM PCNC. Y C.G. = 0.01923  0.52242  1.05434  1.41510  1.80280  2.21112 ********
    ERROR (M)...... -0.03102 -0.15991  0.0     -0.03822 -0.10772 ******** ********
    C.G. VY (M/S)  =   673.     337.     163.      99.      58.      33.
    AT T=0.0.  C.G. VY=1478.      ;  WHEN  VY=0.0.  T=56.30260  AND  Y= 7.60225

PONCELET COEFFICIENTS BASED ON :

    ALL STATIONS   A=      0.0  B=  1.2534  ER=0.08821  EM=-0.1393  CD=  2.5759

    ALL STATIONS   A=      0.0  B=  1.3724  ER=0.09950  EM=-0.1599
```

SHOT 5 (11-11-76 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=193. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.4969 KG LENGTH=0.206 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00059	0.00167	0.00398	0.00686	0.01203	0.02143	*******
NOSE POSITION (M)..							
X-COMP.	0.13270	*******	0.14832	*******	0.24181	*******	*******
Y-COMP.	0.14702	*******	0.80214	*******	1.95176	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	0.11695	*******	0.24971	*******	*******
Y-COMP.	*******	*******	0.59702	*******	1.77034	*******	*******
YAW ANGLE (DEG)....	1.5	0.0	8.2	0.0	0.0	0.0	0.0
C.G. POSITION (M)..							
X-COMP.	0.12731	*******	0.13264	*******	0.24576	*******	*******
Y-COMP.	0.04416	*******	0.69958	*******	1.86105	*******	*******

SHOT 6 (11-11-76 ,NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=202. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.4969 KG LENGTH=0.206 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS)......	0.00[illegible]56	[illegible]165	0.00395	0.00680	0.01196	0.02075	*******
NOSE POSITION (M)..							
X-COMP.	0.11858	0.12006	0.10990	0.06878	-.02396	*******	*******
Y-COMP.	0.15390	0.77671	1.13644	1.55438	1.96114	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.13222	0.14401	0.12146	0.04092	*******	*******
Y-COMP.	*******	0.[illegible]7437	0.94462	1.36750	1.76554	*******	*******
YAW ANGLE (DEG)......	[illegible]	[illegible]3.7	-8.9	-14.9	-17.2	0.0	0.0
C.G. POSITION (M)..							
X-COMP.	0.11756	0.12614	0.12696	0.09512	0.00848	*******	*******
Y-COMP.	0.05801	0.67554	1.04053	1.46094	1.86334	*******	*******

COEF. OF CUBIC POLYNOMIAL: -0.1632D 00 0.5279D 03 -0.6079D 05 0.2580D 07

	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
FROM PONC. Y C.G. =	0.08893	0.52126	1.04053	1.42020	1.84615	2.28196	********
ERROR (M)......	-0.03301	-0.15428	0.0	-0.04074	-0.01719	********	********
C.G. VY (M/S)......	519.	311.	168.	107.	65.	39.	

AT T=0.0. C.G. VY= 791. ; WHEN VY=0.0. T=50.98436 AND Y= 8.45175

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.1711 ER=0.08234 EM=-0.1521 CD= 2.4087

ALL STATIONS A= 0.0 B= 1.1840 ER=0.08246 EM=-0.1543

```
SHOT    7 (11-11-76 ,NO. 4)

DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=274. M/S
SOLID STEP TIER PROJECTILE ; MASS=0.5152 KG  LENGTH=0.219 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00057   0.00165   0.00395   0.00680   0.01201   0.02132   *******

NOSE POSITION (M)..
   X-COMP.          0.10910   *******   0.12375   0.14034   0.16643   0.18142   *******
   Y-COMP.          0.10292   *******   0.77170   1.15366   1.61518   2.09011   *******

TAIL POSITION (M)..
   X-COMP.          *******   *******   0.12424   0.12775   0.14342   0.15110   *******
   Y-COMP.          *******   *******   0.57213   0.93907   1.36631   1.81474   *******

YAW ANGLE (DEG)....    0.7       0.0       0.2      2 2       1.5       0.6       0.0

C.G. POSITION (M)..
   X-COMP.          0.10637   *******   0.12400   0.13391   0.15468   0.16593   *******
   Y-COMP.          -.00891   *******   0.66976   1.04405   1.48806   1.94945   *******

COEF. OF CUBIC POLYNOMIAL:    -0.1435D 00     0.2491D 03     -0.1250D 05     0.2545D 06

FROM PONC. Y C.G. =-0.01117  0.24131   0.66305   1.04405   1.51166   1.93442 ********
   ERROR (M)...... -0.00226 ******** -0.00671   0.0       0.02360 -0.01504 ********
   C.G. VY (M/S)  =    255.      214.      157.      114.       70.       25.
   AT T=0.0.  C.G. VY= 283.      ;  WHEN  VY=0.0.  T= 0.02860  AND  Y= 2.02480

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=      0.0  B=  0.8689  ER=0.07034  EM= 0.1221  CD=  1.8530

   ALL STATIONS    A=   3338.9  B=  0.6388  ER=0.01443  EM= 0.0236
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                        SHOT    8 (12-11-76 .NO. 1)

          DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=256. M/S
          SOLID FLAT NOSE PROJECTILE ; MASS=0.5445 KG  LENGTH=0.225 M

X-RAY STATION.......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)......  0.00058   0.00167   0.00397   0.00681   0.01206   0.02131   *******

NOSE POSITION (M)..
   X-COMP.            0.12258   0.12261   0.13329   *******   0.15966   0.19182   *******
   Y-COMP.            0.14351   0.39036   0.78565   *******   1.59049   2.09810   *******

TAIL POSITION (M)..
   X-COMP.            *******   0.11587   0.12383   0.12971   0.14607   0.17013   *******
   Y-COMP.            *******   0.17711   0.58817   0.96201   1.35751   1.86853   *******

YAW ANGLE (DEG).....    0.8       1.8       2.7       1.1       3.2       6.7       0.0

C.G. POSITION (M)..
   X-COMP.            0.11964   0.11924   0.12856   0.13383   0.15287   0.18098   *******
   Y-COMP.            0.03105   0.28374   0.68691   1.07443   1.47400   1.98332   *******

COEF. OF CUBIC POLYNOMIAL:    -0.10770 00     0.25160 03    -0.13600 05     0.30030 06

FROM PONC. Y C.G. =-0.00056   0.26020   0.68691   1.06826   1.53860   1.97104 ********
   ERROR (M)....... -0.03161 -0.02353   0.0      -0.00618   0.06460 -0.01228 ********
   C.G. VY (M/S)  =    265.      219.      158.      114.       70.       28.
   AT T=0.0.  C.G. VY= 298.          ;  WHEN  VY=0.0.   T= 0.03032  AND  Y= 2.09318

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=       0.0   B=   0.7710   ER=0.00544   EM= 0.0089   CD=  1.7376
   STATIONS 2-5    A=       0.0   B=   0.7345   ER=0.03585   EM=-0.0530   CD=  1.7230
   STATIONS 3-6    A=       0.0   B=   0.9837   ER=0.01800   EM=-0.0239   CD=  2.2171
   ALL STATIONS    A=       0.0   B=   0.9614   ER=0.05487   EM=-0.0938   CD=  2.1669

   STATIONS 1-4    A=    2261.0   B=   0.6916   ER=0.00629   EM= 0.0101
   STATIONS 2-5    A=    2261.0   B=   0.6396   ER=0.03076   EM=-0.0454
   STATIONS 3-6    A=    2261.0   B=   0.7957   ER=0.03778   EM= 0.0515
   ALL STATIONS    A=    2261.0   B=   0.7487   ER=0.03560   EM= 0.0585

   STATIONS 1-4    A=       0.0   B=   0.7704   ER=0.00544   EM= 0.0089
   STATIONS 2-5    A=   13183.8   B=   0.0884   ER=0.00402   EM=-0.0065
   STATIONS 3-6    A=       0.0   B=   0.9855   ER=0.01803   EM=-0.0243
   ALL STATIONS    A=    2928.6   B=   0.6812   ER=0.03440   EM= 0.0646
```

SHOT 9 (12-11-76 .NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=236. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.4968 KG LENGTH=0.206 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00060	0.00171	0.00398	0.00684	0.01211	0.02143	*******
NOSE POSITION (M)..							
X-COMP.	0.13018	0.12972	0.13501	*******	0.13044	0.10135	*******
Y-COMP.	0.14994	0.39560	0.78169	*******	1.55066	1.97001	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.12553	0.13257	0.13937	0.13830	*******	0.11524
Y-COMP.	*******	0.20336	0.57137	0.91417	1.33402	*******	2.00435
YAW ANGLE (DEG)....	0.4	0.6	0.1	-0.6	-2.3	-4.2	-2.0
C.G. POSITION (M)..							
X-COMP.	0.12874	0.12763	0.13379	0.13703	0.13437	0.11622	0.10823
Y-COMP.	0.04695	0.29948	0.67653	1.01714	1.44234	1.86809	2.10711

COEF. OF CUBIC POLYNOMIAL: -0.73870-01 0.22790 03 -0.11260 05 0.22650 06

FROM FCNC. Y C.G. =	0.02759	0.27909	0.67653	1.03744	1.47671	1.86121	********
ERROR (M).......	-0.01936	-0.02039	0.0	0.02030	0.03437	-0.00688	********
C.G. VY (M/S) =	250.	205.	149.	107.	64.	22.	

AT T=0.0. C.G. VY= 283. ; WHEN VY=0.0. T= 0.02828 AND Y= 1.93643

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A=	0.0	B=	0.9905	ER=0.00304	EM= 0.0042	CD=	2.0369
STATIONS 2-5	A=	0.0	B=	0.8837	ER=0.00866	EM=-0.0107	CD=	1.8172
STATIONS 3-6	A=	0.0	B=	0.7953	ER=0.06227	EM=-0.0666	CD=	1.6355
ALL STATIONS	A=	0.0	B=	1.0563	ER=0.05208	EM=-0.0897	CD=	2.1722
STATIONS 1-4	A=	2333.6	B=	0.8943	ER=0.00339	EM= 0.0056		
STATIONS 2-5	A=	3452.6	B=	0.6761	ER=0.00217	EM=-0.0032		
STATIONS 3-6	A=	4623.3	B=	0.3524	ER=0.02552	EM=-0.0333		
ALL STATIONS	A=	3152.5	B=	0.7119	ER=0.02205	EM= 0.0344		

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                          SHOT   10 (12-11-76 ,NO. 4)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=239. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.4968 KG   LENGTH=0.206 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS).....  0.00057   0.00175   0.00402   0.00590   0.01214   0.02318   *******

NOSE POSITION (M)..
   X-COMP.           0.12563   *******   0.15771   0.19746   0.23925   *******   *******
   Y-COMP.           0.12283   *******   1.07678   1.50852   1.94935   *******   *******

TAIL POSITION (M)..
   X-COMP.           *******   *******   0.14060   *******   0.21925   *******   0.24468
   Y-COMP.           *******   *******   0.90307   *******   1.75948   *******   2.00207

YAW ANGLE (DEG)....    0.6       2.7       2.7       8.0       7.1       0.0      -1.3

C.G. POSITION (M)..
   X-COMP.           0.12329   *******   0.14916   0.18473   0.22925   *******   0.24001
   Y-COMP.           0.01986   *******   0.98992   1.40631   1.85442   *******   2.10496

COEF. OF CUBIC POLYNOMIAL:    -0.2091D 00     0.4229D 03    -0.3594D 05     0.1245D 07

FROM FONC. Y C.G. = 0.01272  0.43620   0.98992   1.43251   1.84263   1.67433  ********
   ERROR (M)....... -0.00713 ********  0.0       0.02620  -0.01179 ********  ********
   C.G. VY (M/S)  =    420.      308.      194.      120.       44.     *****
   AT T=0.0,  C.G. VY= 505.        ;  WHEN  VY=0.0,  T= 0.01627  AND  Y= 1.93108

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=       0.0  B=   0.9063  ER=0.07878  EM= 0.1161  CD=  1.8636

   ALL STATIONS    A= 10166.2  B=   0.6563  ER=0.01709  EM= 0.0262
```

SHOT 11 (12-11-76 .NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=240. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.4965 KG LENGTH=0.206 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS)......	0.00059	0.00178	0.00406	0.00693	0.01217	0.02322	*******
NOSE POSITION (M)..							
X-COMP.	0.12923	0.12920	0.13588	0.12907	0.12118	0.08545	*******
Y-COMP.	0.17602	0.44847	0.83744	1.18016	1.60915	2.09965	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.12329	0.13429	0.14110	0.13473	0.11111	*******
Y-COMP.	*******	0.22244	0.63370	0.98057	1.39294	1.89132	*******
YAW ANGLE (DEG)....	0.6	1.5	-0.9	-3.0	-4.3	-4.8	0.0
C.G. POSITION (M)..							
X-COMP.	0.12707	0.12625	0.13509	0.13509	0.12796	0.09828	*******
Y-COMP.	0.07304	0.33546	0.73557	1.08037	1.50105	1.99549	*******

COEF. OF CUBIC POLYNOMIAL: -0.5569D-01 0.2363D 03 -0.1176D 05 0.2319D 06

FROM POMC. Y C.G. =	0.04258	0.32544	0.73557	1.10423	1.54865	1.98760	********
ERROR (M).......	-0.03047	-0.01001	0.0	0.02387	0.04760	-0.00788	********
C.G. VY (M/S) =	287.	214.	152.	109.	65.	19.	

AT T=0.0. C.G. VY= 304. ; WHEN VY=0.0. T= 0.02962 AND Y= 2.04777

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.3617	ER=0.00775	EM=-0.0096	CD= 1.7709
STATIONS 2-5	A= 0.0	B= 0.9473	ER=0.00897	EM=-0.0108	CD= 1.9468
STATIONS 3-6	A= 0.0	B= 0.7961	ER=0.07531	EM=-0.0816	CD= 1.6360
ALL STATIONS	A= 0.0	B= 1.0587	ER=0.06174	EM=-0.1105	CD= 2.1757

STATIONS 1-4	A= 8665.3	B= 0.5449	ER=0.00364	EM=-0.0046
STATIONS 2-5	A= 3536.9	B= 0.7522	ER=0.00358	EM=-0.0047
STATIONS 3-6	A= 4424.3	B= 0.3565	ER=0.03638	EM=-0.0481
ALL STATIONS	A= 2899.0	B= 0.7350	ER=0.02802	EM= 0.0476

SHOT 12 (3-12-76 .NO. 1)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=287. M/S
SOLID STEP TIER PROJECTILE ; MASS=0.5160 KG LENGTH=0.219 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00058	0.00177	0.00396	0.00664	0.01238	0.01984	*******
NOSE POSITION (M)..							
X-COMP.	0.12928	*******	*******	0.12606	0.09970	*******	*******
Y-COMP.	0.14141	*******	*******	1.56096	2.16833	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.12978	*******	0.13028	*******	*******	0.10752
Y-COMP.	*******	0.20121	*******	1.36562	*******	*******	2.14901
YAW ANGLE (DEG)....	0.1	0.2	-0.8	-1.6	-1.2	0.0	-0.8
C.G. POSITION (M)..							
X-COMP.	0.12889	0.13053	*******	0.12822	0.10438	*******	0.10453
Y-COMP.	0.02955	0.30834	*******	1.46118	2.05656	*******	2.25610

COEF. OF CUBIC POLYNOMIAL: -0.99870-01 0.2161D 03 0.1012D 05 -0.1091D 07

FROM PONC. Y C.G. =	0.01181	0.30834	0.80401	1.31914	2.08660	2.39765	********
ERROR (M).......	-0.01774	0.0	********	-0.14204	0.03004	********	********
C.G. VY (M/S) =	258.	242.	211.	174.	94.	*****	

AT T=0.0. C.G. VY= 266. ; WHEN VY=0.0. T= 0.01910 AND Y= 2.40154

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.3678 ER=0.10750 EM=-0.1755 CD= 0.7857

ALL STATIONS A= 13937.9 B= 0.0005 ER=0.08444 EM=-0.1420

SHOT 13 (3-12-76 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID STEP TIER PROJECTILE ; MASS=0.5157 KG LENGTH=0.219 M

X-RAY STATION......	NC.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECCNDS).....	0.00056	0.00173	0.00394	0.00660	0.01234	0.02182	*******
NOSE POSITION (M)..							
X-COMP.	0.12342	*******	0.11986	0.05570	*******	*******	*******
Y-COMP.	0.12892	*******	0.81550	1.62911	*******	*******	*******
TAIL POSITION (M)..							
X-CCMP.	*******	*******	*******	*******	0.02747	*******	-.01574
Y-CCMP.	*******	*******	*******	*******	1.82239	*******	2.02130
YAW ANGLE (DEG)....	0.2	0.0	-3.1	-8.6	-6.6	0.0	0.9
C.G. POSITION (M)..							
X-CCMP.	0.12283	*******	0.13194	0.08878	0.00319	*******	-.01256
Y-COMP.	0.01706	*******	0.70429	1.52225	1.92674	*******	2.12839

COEF. OF CUBIC POLYNOMIAL: -0.2819D-02 0.2806D 01 0.6009D 05 -0.3860D 07

FRCM PONC. Y C.G. =	-0.48589	-0.03021	0.70429	1.37498	2.02237	0.69407	********
ERROR (M)......	-0.50295	********	0.0	-0.14727	0.09563	********	********
C.G. VY (M/S)	409.	370.	296.	208.	17.	*****	

AT T=0.0. C.G. VY= 427. ; WHEN VY=0.0. T= 0.01286 AND Y= 2.02679

PONCELET CCEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.4007 ER=0.45598 EM=-0.5919 CD= 0.8554

ALL STATIONS A= 33224.2 B= 0.0001 ER=0.30757 EM=-0.5030

```
                              SHOT  15 ( 3-12-76 ,NO. 4)

       DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=203. M/S
       SOLID FLAT NOSE PROJECTILE : MASS=0.5425 KG  LENGTH=0.225 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS).....  0.00065   0.00244   0.00542   0.00927   0.01531   0.03017   *******

NOSE POSITION (M)..
   X-COMP.           0.13529   0.13194   0.13604   0.12820   *******   *******   0.14802
   Y-COMP.           0.12441   0.41884   0.78575   1.44227   *******   *******   2.12679

TAIL POSITION (M)..
   X-COMP.           *******   0.13165   0.13725   0.13331   *******   *******   0.13822
   Y-COMP.           *******   0.16944   0.58120   1.25894   *******   *******   1.93649

YAW ANGLE (DEG)....   -0.3      -0.4      -0.5      -2.7       2.7       0.0       1.5

C.G. POSITION (M)..
   X-COMP.           0.13627   0.13180   0.13665   0.13076   *******   *******   0.14312
   Y-COMP.           0.01191   0.29414   0.68348   1.35061   *******   *******   2.03164

COEF. OF CUBIC POLYNOMIAL:    -0.1124D 00    0.2016D 03    -0.1771D 05    0.1400D 07

FROM PCNC. Y C.G. = 0.04344   0.29414   0.71204   1.24877   2.08678   4.12495 ********
   ERROR (M)......  0.03152   0.0       0.02856 -0.10183 ******** ******** ********
   C.G.-VY (M/S)  =   141.      140.      140.      139.      138.      136.
   AT T=0.0. C.G. VY= 141.      ;  WHEN  VY=0.0.  T=********  AND  Y=********

FONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=     0.0  B=  0.0000  ER=0.06194  EM=-0.0982  CD=  0.0000

   ALL STATIONS   A=  2261.0  B=  0.1198  ER=0.11563  EM=-0.1986

   ALL STATIONS   A=     0.0  B=  0.0079  ER=0.06372  EM=-0.1018
```

SHOT 16 (3-12-76 .NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=202. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5425 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECCNDS).....	0.00067	0.00247	0.00546	0.00933	0.01536	0.03171	*******
NOSE POSITICN (M)..							
X-CCMP.	0.13773	0.13585	0.14698	*******	0.20348	0.22930	0.22190
Y-COMP.	0.10550	0.39282	0.78075	*******	1.51134	1.97426	2.13419
TAIL POSITICN (M)..							
X-CCMP.	*******	*******	*******	*******	*******	0.22757	0.23631
Y-CCMP.	*******	*******	*******	*******	*******	1.73601	1.92659
YAW ANGLE (DEG)....	0.0	1.0	2.4	0.0	3.7	3.0	-0.5
C.G. POSITICN (M)..							
X-CCMP.	0.13773	0.13192	0.13757	*******	0.18899	0.22844	0.22911
Y-COMP.	-.00700	0.28039	0.66864	*******	1.39978	1.85514	2.03039

COEF. OF CUBIC POLYNOMIAL: -0.1232D 00 0.1783D 03 -0.6563D 04 0.9166D 05

FRCM PCNC. Y C.G. =	-0.03485	0.27131	0.66864	1.04707	1.44519	1.85000	********
ERROR (M)......	-0.02785	-0.00907	0.0	********	0.04542	-0.00514	********
C.G. VY (M/S) =	189.	154.	115.	83.	52.	2.	

AT T=0.C. C.G. VY= 207. ; WHEN VY=0.0. T= 0.03243 AND Y= 1.85066

PONCELET CCEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.0943 ER=0.11246 EM=-0.1653 CD= 2.4573

ALL STATIONS A= 2261.0 B= 0.6583 ER=0.02927 EM=-0.0428

ALL STATIONS A= 2568.0 B= 0.5894 ER=0.02714 EM= 0.0454

SHOT 17 (3-12-76 .NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=202. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5425 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00067	0.00247	0.00546	0.00933	0.01536	0.03171	*******
NOSE POSITION (M)..							
X-COMP.	0.13574	0.13775	0.14687	*******	0.20231	0.22728	0.22083
Y-COMP.	0.36048	0.17293	0.78050	*******	1.51111	1.97552	2.13230
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	*******	*******	0.22217	0.23037
Y-COMP.	*******	*******	*******	*******	*******	1.75094	1.92816
YAW ANGLE (DEG)....	1.0	0.0	2.6	0.0	4.1	2.5	-0.4
C.G. POSITION (M)..							
X-COMP.	0.13201	0.13775	0.13667	*******	0.18626	0.22473	0.22560
Y-COMP.	0.24804	0.06043	0.66846	*******	1.39976	1.86323	2.03023

COEF. OF CUBIC POLYNOMIAL: 0.7930D-01 0.7870D 02 0.1706D 04 -0.7616D 05

FROM POLY. Y C.G. =	0.17969	0.37669	0.66846	0.98713	1.37069	1.86545	********
ERROR (M)......	-0.06835	0.31626	0.0	********	-0.02907	0.00222	********
C.G. VY (M/S) =	115.	105.	91.	74.	54.	9.	

AT T=0.0. C.G. VY= 119. ; WHEN VY=0.0. T= 0.03528 AND Y= 1.88119

FONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.9549 ER=0.16976 EM= 0.2948 CD= 2.1442

ALL STATIONS A= 2261.0 B= 0.5000 ER=0.18467 EM= 0.3060

ALL STATIONS A= 2466.5 B= 0.2471 ER=0.16244 EM= 0.3163

SHOT 18 (28-02-77 ,NO. 1)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=116. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5426 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECCNDS).....	0.00063	0.00242	0.00540	0.00930	0.01531	0.03168	*******
NOSE POSITION (M)..							
X-COMP.	0.12555	0.12556	0.13373	0.13842	0.16758	*******	0.15649
Y-COMP.	0.11878	0.41518	0.80440	1.16932	1.57130	*******	1.77434
TAIL POSITICN (M)..							
X-CCMP.	*******	0.11951	0.12651	0.13200	0.14737	*******	0.15971
Y-COMP.	*******	[illegible]	0.58029	0.95602	1.34120	*******	1.55853
YAW ANGLE (DEG)....	0.0	1.2	1.3	3.5	4.1	0.0	-0.5
C.G. POSITION (M)..							
X-COMP.	0.12555	0.12254	0.13012	0.13521	0.15748	*******	0.15810
Y-COMP.	0.00628	0.29751	0.69235	1.06267	1.45625	*******	1.66644

COEF. OF CUBIC POLYNOMIAL: -0.10850 00 0.18730 03 -0.82010 04 0.17260 06

FROM PONC. Y C.G. =	0.00052	0.29937	0.69235	1.06610	1.43389	1.58099	********
ERROR (M)......	-0.00576	0.00186	0.0	0.00343	-0.02236	********	********
C.G. VY (M/S) =	184.	152.	114.	80.	44.	*****	

AT T=0.C. C.G. VY= 198. ; WHEN VY=0.0. T= 0.02563 AND Y= 1.65498

FONCELET CCEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.8123 ER=0.02434 EM= 0.0364 CD= 1.8243

ALL STATIONS A= 2261.0 B= 0.6198 ER=0.00815 EM=-0.0115

ALL STATIONS A= 4000.0 B= 0.5000 ER=0.01171 EM=-0.0224

SHOT 19 (28-02-77 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY= 84. M/S
SOLID FLAT NOSE PROJECTILE : MASS=0.5426 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00065	0.00243	0.00543	0.00932	0.01456	0.03171	*******
NOSE POSITION (M)..							
X-COMP.	0.12762	*******	0.13295	0.08675	0.17340	0.20067	*******
Y-COMP.	0.10856	*******	0.72301	1.06973	1.40707	1.93518	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.11215	*******	*******	*******	0.18066	0.19571
Y-COMP.	*******	0.11383	*******	*******	*******	1.75813	1.92940
YAW ANGLE (DEG)....	1.1	1.3	2.4	-3.3	5.1	7.1	2.5
C.G. POSITION (M)..							
X-COMP.	0.12330	0.11725	0.12354	0.09968	0.15348	0.19067	0.20552
Y-COMP.	-.00346	0.22621	0.61090	0.95798	1.29635	1.84666	2.04147

COEF. OF CUBIC POLYNOMIAL: -0.1138D 00 0.1594D 03 -0.5486D 04 0.7593D 05

FROM FCNC. Y C.G. =	-0.03367	0.24326	0.61090	0.96633	1.33218	1.84260	*******
ERROR (M).......	-0.03022	0.01705	0.0	0.00835	0.03584	-0.00405	*******
C.G. VY (M/S) =	172.	141.	107.	79.	53.	12.	

AT T=0.C. C.G. VY= 187. ; WHEN VY=0.0. T= 0.03859 AND Y= 1.88457

FORCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.5356	ER=0.01980	EM=-0.0251	CD=	1.2029
STATIONS 2-5	A= 0.0	B= 0.9419	ER=0.01080	EM=-0.0130	CD=	2.1155
STATIONS 3-6	A= 0.0	B= 0.8872	ER=0.06700	EM=-0.0724	CD=	1.9925
ALL STATIONS	A= 0.0	B= 1.0498	ER=0.06023	EM=-0.1148	CD=	2.3579
STATIONS 1-4	A= 2261.0	B= 0.3641	ER=0.01852	EM=-0.0236		
STATIONS 2-5	A= 2261.0	B= 0.7141	ER=0.00439	EM= 0.0062		
STATIONS 3-6	A= 2261.0	B= 0.4510	ER=0.02706	EM=-0.0341		
ALL STATIONS	A= 2261.0	B= 0.5212	ER=0.02627	EM= 0.0492		
STATIONS 1-4	A= 7265.7	B= 0.0011	ER=0.01581	EM=-0.0210		
STATIONS 2-5	A= 3375.0	B= 0.6210	ER=0.00348	EM=-0.0045		
STATIONS 3-6	A= 2157.4	B= 0.4683	ER=0.02686	EM=-0.0347		
ALL STATIONS	A= 1754.2	B= 0.6453	ER=0.02269	EM= 0.0358		

SHOT 20 (28-02-77 .NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=102. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5419 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00[illegible]	0.00248	0.00547	0.00934	0.01496	0.03171	*******
NOSE POSITION (M)..							
X-COMP.	0.12776	*******	0.14025	0.15830	0.20809	0.23065	*******
Y-COMP.	0.10839	*******	0.71938	1.06291	1.44609	1.96537	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.11454	*******	*******	*******	0.24995	0.22873
Y-COMP.	*******	0.14175	*******	*******	*******	1.75185	2.14737
YAW ANGLE (DEG)....	1.0	1.5	4.0	5.7	8.9	-3.3	-1.3
C.G. POSITION (M)..							
X-COMP.	0.12383	0.12043	0.12459	0.13626	0.17370	0.24030	0.22363
Y-COMP.	-.00404	0.25410	0.60797	0.95259	1.33898	1.85861	2.25975

COEF. OF CUBIC POLYNOMIAL: -0.9978D-01 0.1510D 03 -0.4459D 04 0.5187D 05

FROM PONC. Y C.G. =	-0.01512	0.24925	0.60797	0.96905	1.34835	1.85252	********
ERROR (M)......	-0.01108	-0.00485	0.0	0.01646	0.00937	-0.00609	********
C.G. VY (M/S) =	159.	135.	107.	81.	55.	9.	

AT T=0.C. C.G. VY= 170. ; WHEN VY=0.0. T= 0.03558 AND Y= 1.86941

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.7306	ER=0.00469	EM=-0.0064	CD= 1.6389
STATIONS 2-5	A= 0.0	B= 0.7628	ER=0.00202	EM= 0.0025	CD= 1.7111
STATIONS 3-6	A= 0.0	B= 0.7370	ER=0.09960	EM=-0.1219	CD= 1.6532
ALL STATIONS	A= 0.0	B= 1.0142	ER=0.06304	EM=-0.1087	CD= 2.2750
STATIONS 1-4	A= 2261.0	B= 0.5622	ER=0.00353	EM=-0.0044	
STATIONS 2-5	A= 2261.0	B= 0.5367	ER=0.00797	EM= 0.0122	
STATIONS 3-6	A= 2261.0	B= 0.5000	ER=0.19064	EM=-0.2736	
ALL STATIONS	A= 2261.0	B= 0.5000	ER=0.01042	EM= 0.0166	
STATIONS 1-4	A= 2836.2	B= 0.5062	ER=0.00242	EM=-0.0034	
STATIONS 2-5	A= 812.2	B= 0.6815	ER=0.00372	EM= 0.0057	
STATIONS 3-6	A= 3891.0	B= 0.0072	ER=0.02497	EM=-0.0365	
ALL STATIONS	A= 2243.4	B= 0.5044	ER=0.01041	EM= 0.0165	

SHOT 21 (28-02-77 ,NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=123. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5415 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00071	0.00250	0.00548	0.00937	0.01497	0.03171	*******
NOSE POSITION (M)..							
X-COMP.	0.12696	*******	0.13819	0.15718	0.21166	0.23162	*******
Y-COMP.	0.10378	*******	0.72143	1.07434	1.43402	2.12499	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.10322	*******	*******	*******	0.25371	0.23189
Y-COMP.	*******	0.13653	*******	*******	*******	1.80164	2.15030
YAW ANGLE (DEG)....	1.4	1.9	3.9	5.3	6.2	-2.5	-1.9
C.G. POSITION (M)..							
X-COMP.	0.12146	0.11548	0.12312	0.13668	0.18750	0.24267	0.22443
Y-COMP.	-.00859	0.24880	0.60994	0.96372	1.32414	1.96332	2.26255

COEF. OF CUBIC POLYNOMIAL: -0.1182D 00 0.1593D 03 -0.5332D 04 0.7504D 05

FROM PONC. Y C.G. =	-0.02936	0.24477	0.60994	0.97259	1.35380	1.95995	********
ERROR (M).......	-0.02077	-0.00402	0.0	0.00887	0.02965	-0.00337	********
C.G. VY (M/S) =	169.	140.	108.	81.	57.	20.	

AT T=0.0, C.G. VY= 184. ; WHEN VY=0.0, T= 0.04608 AND Y= 2.09990

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.6917	ER=0.00530	EM=-0.0069	CD= 1.5503
STATIONS 2-5	A= 0.0	B= 0.7872	ER=0.00863	EM=-0.0114	CD= 1.7644
STATIONS 3-6	A= 0.0	B= 0.7843	ER=0.04368	EM=-0.0480	CD= 1.7579
ALL STATIONS	A= 0.0	B= 0.9228	ER=0.03863	EM=-0.0761	CD= 2.0683
STATIONS 1-4	A= 2261.0	B= 0.5210	ER=0.00362	EM=-0.0047	
STATIONS 2-5	A= 2261.0	B= 0.5507	ER=0.00189	EM=-0.0026	
STATIONS 3-6	A= 2261.0	B= 0.3859	ER=0.02656	EM= 0.0316	
ALL STATIONS	A= 2261.0	B= 0.5000	ER=0.04747	EM=-0.1009	
STATIONS 1-4	A= 1671.4	B= 0.5663	ER=0.00404	EM=-0.0053	
STATIONS 2-5	A= 1998.7	B= 0.5864	ER=0.00253	EM=-0.0032	
STATIONS 3-6	A= 1578.5	B= 0.4922	ER=0.01586	EM=-0.0188	
ALL STATIONS	A= 1315.2	B= 0.6307	ER=0.01683	EM= 0.0297	

SHOT 22 (28-02-77 .NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=173. M/S
SOLID FLAT NOSE PROJECTILE : MASS=0.5430 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00068	0.00247	0.00547	0.00933	0.01497	0.03171	*******
NOSE POSITION (M)..							
X-COMP.	0.12882	0.12954	0.14305	0.17843	0.23910	0.22561	0.22017
Y-COMP.	0.12908	0.45422	0.86903	1.26046	1.68637	2.06055	2.06403
TAIL POSITION (M)..							
X-COMP.	*******	0.11589	0.11345	0.12610	0.17934	0.25347	0.25156
Y-COMP.	*******	0.22139	0.64180	1.02768	1.44654	1.83953	1.85296
YAW ANGLE (DEG)....	1.3	3.1	7.1	9.5	12.4	-5.9	-7.0
C.G. POSITION (M)..							
X-COMP.	0.12391	0.12272	0.12825	0.15227	0.20922	0.23954	0.23587
Y-COMP.	0.01669	0.33781	0.75542	1.14407	1.56646	1.95004	1.95850

COEF. OF CUBIC POLYNOMIAL: -0.9482D-01 0.1843D 03 -0.5955D 04 0.6868D 05

FROM PONC. Y C.G. =	0.00321	0.32584	0.75542	1.16985	1.58158	1.94825	********
ERROR (M)......	-0.01348	-0.01197	0.0	0.02578	0.01513	-0.00179	********
C.G. VY (M/S) =	197.	164.	125.	91.	57.	*****	

AT T=0.0. C.G. VY= 212. ; WHEN VY=0.0. T= 0.02908 AND Y= 1.96073

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.7549	ER=0.00544	EM=-0.0084	CD= 1.6968
STATIONS 2-5	A= 0.0	B= 0.7481	ER=0.00301	EM=-0.0051	CD= 1.6815
STATIONS 3-6	A= 0.0	B= 0.8131	ER=0.16149	EM=-0.1982	CD= 1.8274
ALL STATIONS	A= 0.0	B= 1.0481	ER=0.14181	EM= 0.2292	CD= 2.3556
STATIONS 1-4	A= 2261.0	B= 0.6298	ER=0.00356	EM=-0.0056	
STATIONS 2-5	A= 2261.0	B= 0.5757	ER=0.00690	EM= 0.0107	
STATIONS 3-6	A= 2261.0	B= 0.3802	ER=0.10597	EM=-0.1047	
ALL STATIONS	A= 2261.0	B= 0.6857	ER=0.04912	EM= 0.0742	
STATIONS 1-4	A= 4557.1	B= 0.4908	ER=0.00125	EM=-0.0019	
STATIONS 2-5	A= 944.1	B= 0.6804	ER=0.00376	EM=-0.0046	
STATIONS 3-6	A= 5018.0	B= 0.0036	ER=0.03945	EM=-0.0540	
ALL STATIONS	A= 3597.3	B= 0.4523	ER=0.01563	EM= 0.0258	

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                              SHOT   23 ( 1-03-77 ,NO. 1)

        DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=221. M/S
        SOLID FLAT NOSE PROJECTILE ; MASS=0.5424 KG  LENGTH=0.225 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS).....  0.00069   0.00248   0.00548   0.00937   0.01543   0.03171   *******

NOSE POSITION (M)..
   X-COMP.           0.11152   0.11378   0.12685   0.15296   0.18571   0.21539   0.21178
   Y-COMP.           0.12496   0.44924   0.87178   1.26257   1.69753   2.02830   2.02280

TAIL POSITION (M)..
   X-COMP.           *******   0.10242   0.10917   0.11307   0.15281   0.16305   0.15747
   Y-COMP.           *******   0.21485   0.63883   1.03264   1.46644   1.81370   1.81623

YAW ANGLE (DEG)....    0.5       2.4       3.8       6.3       7.8      14.4      15.8

C.G. POSITION (M)..
   X-COMP.           0.10936   0.10810   0.11801   0.13302   0.16926   0.18922   0.18463
   Y-COMP.           0.01248   0.33205   0.75531   1.14761   1.58199   1.92100   1.91952

COEF. OF CUBIC POLYNOMIAL:    -0.1040D 00     0.1866D 03    -0.6147D 04     0.7176D 05

FROM PONC. Y C.G. =-0.00480   0.32183   0.75531   1.17198   1.60179   1.91853 ********
   ERROR (M).......-0.01728  -0.01021   0.0       0.02437   0.01980  -0.00247 ********
   C.G. VY (M/S)  =   201.      166.      126.       90.       54.     *****
   AT T=0.0.  C.G. VY= 217.       ;  WHEN  VY=0.0.  T= 0.02859  AND  Y= 1.93643

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=     0.0  B=   0.7403  ER=0.00684  EM=-0.0100  CD=  1.6621
   STATIONS 2-5    A=     0.0  B=   0.7753  ER=0.00592  EM=-0.0078  CD=  1.7407
   STATIONS 3-6    A=     0.0  B=   0.8626  ER=0.15992  EM=-0.1923  CD=  1.9366
   ALL STATIONS    A=     0.0  B=   1.0633  ER=0.15148  EM= 0.2506  CD=  2.3872

   STATIONS 1-4    A=  2261.0  B=   0.6104  ER=0.00451  EM=-0.0067
   STATIONS 2-5    A=  2261.0  B=   0.5983  ER=0.00417  EM= 0.0064
   STATIONS 3-6    A=  2261.0  B=   0.4291  ER=0.10061  EM= 0.0998
   ALL STATIONS    A=  2261.0  B=   0.7177  ER=0.05394  EM=-0.0848

   STATIONS 1-4    A=  4463.9  B=   0.4855  ER=0.00237  EM=-0.0037
   STATIONS 2-5    A=  1832.2  B=   0.6358  ER=0.00362  EM=-0.0044
   STATIONS 3-6    A=  5268.2  B=   0.0176  ER=0.03389  EM=-0.0486
   ALL STATIONS    A=  3670.6  B=   0.4667  ER=0.01670  EM= 0.0244
```

SHOT 24 (1-03-77 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY= 93. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5420 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00073	0.00252	0.00553	0.00937	0.01543	0.03171	*******
NOSE POSITION (M)..							
X-COMP.	0.12166	0.12185	0.12694	0.13771	0.12986	*******	*******
Y-COMP.	0.12088	0.41260	0.79887	1.16162	1.56863	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.11619	0.12711	0.13112	0.13802	0.12094	0.10746
Y-COMP.	*******	0.17899	0.57235	0.93492	1.33734	1.95775	2.12649
YAW ANGLE (DEG)....	-3.4	0.9	-0.5	-2.8	-3.0	0.4	1.1
C.G. POSITION (M)..							
X-COMP.	0.13498	0.11902	0.12703	0.13442	0.13354	0.12231	0.11178
Y-COMP.	0.00917	0.29580	0.68561	1.04827	1.45299	2.07024	2.23891

COEF. OF CUBIC POLYNOMIAL: -0.1089D 00 0.1732D 03 -0.5950D 04 0.8502D 05

FROM PONC. Y C.G. =	-0.01446	0.28755	0.68561	1.06500	1.48873	2.06565	********
ERROR (M)......	-0.02363	-0.00825	0.0	0.01673	0.03575	-0.00459	********
C.G. VY (M/S) =	188.	153.	115.	85.	57.	19.	

AT T=0.0. C.G. VY= 207. ; WHEN VY=0.0. T= 0.04350 AND Y= 2.17236

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.7469	ER=0.00562	EM=-0.0079	CD= 1.6756
STATIONS 2-5	A= 0.0	B= 0.8012	ER=0.00700	EM=-0.0082	CD= 1.7975
STATIONS 3-6	A= 0.0	B= 0.7366	ER=0.06226	EM=-0.0654	CD= 1.6525
ALL STATIONS	A= 0.0	B= 0.9263	ER=0.04956	EM=-0.0936	CD= 2.0782
STATIONS 1-4	A= 2261.0	B= 0.6063	ER=0.00431	EM=-0.0057	
STATIONS 2-5	A= 2261.0	B= 0.5889	ER=0.00253	EM= 0.0040	
STATIONS 3-6	A= 2261.0	B= 0.2586	ER=0.12736	EM= 0.1999	
ALL STATIONS	A= 2261.0	B= 0.5000	ER=0.03119	EM= 0.0475	
STATIONS 1-4	A= 2205.4	B= 0.6040	ER=0.00371	EM=-0.0054	
STATIONS 2-5	A= 2205.4	B= 0.6040	ER=0.00283	EM=-0.0038	
STATIONS 3-6	A= 2203.3	B= 0.3676	ER=0.02431	EM=-0.0318	
ALL STATIONS	A= 1500.9	B= 0.6316	ER=0.02100	EM= 0.0357	

```
                              SHOT   25 ( 1-03-77 .NO. 3)

          DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=123. M/S
          SOLID FLAT NOSE PROJECTILE ; MASS=0.5414 KG  LENGTH=0.225 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS).....  0.00068   0.00247   0.00547   0.00937   0.01543   0.03171   *******

NOSE POSITION (M)..
   X-COMP.           0.11949   0.13435   0.15954   0.19300   0.22702   *******   *******
   Y-COMP.           0.11153   0.72171   1.09196   1.46971   1.99694   *******   *******

TAIL POSITION (M)..
   X-COMP.           *******   0.11543   0.12312   0.15776   0.21745   *******   *******
   Y-COMP.           *******   0.52934   0.88712   1.23833   1.79632   *******   *******

YAW ANGLE (DEG)....    1.0       5.1       6.8       8.4       5.2       0.0      -0.5

C.G. POSITION (M)..
   X-COMP.           0.11556   0.12489   0.14133   0.17538   0.22224   *******   *******
   Y-COMP.           -.00090   0.62553   0.98954   1.35402   1.89663   *******   *******

COEF. OF CUBIC POLYNOMIAL:   -0.2202D 00    0.3936D 03   -0.3637D 05    0.1281D 07

FROM FCNC. Y C.G. = 0.15087   0.56686   0.98954   1.33736   1.69289   2.24269 ********
   ERROR (M)......  0.15177  -0.05866   0.0      -0.01666  -0.20374 ******** ********
   C.G. VY (M/S)  =   301.      183.      111.       73.       48.       25.
   AT T=0.0.  C.G. VY= 399.       ;  WHEN  VY=0.0.  T=********  AND  Y= 9.05113

FORCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=      0.0  B=   1.3266  ER=0.12611  EM=-0.2279  CD=  2.9729

   ALL STATIONS    A=   2261.0  B=   1.2326  ER=0.15126  EM=-0.2817

   ALL STATIONS    A=      0.0  B=   1.1942  ER=0.13064  EM=-0.2037
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                          SHOT   26 ( 1-03-77 ,NO. 4)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=122. M/S
      SOLID STEP TIER PROJECTILE ; MASS=0.5154 KG   LENGTH=0.219 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00075   0.00255   0.00554   0.00944   0.01543   0.03171   *******

NOSE POSITION (M)..
   X-COMP.          0.12365   0.12290   0.13621   *******   *******   0.23150   0.20409
   Y-COMP.          0.11058   0.39879   0.77323   *******   *******   1.96664   2.15005

TAIL POSITION (M)..
   X-COMP.          *******   0.10567   *******   *******   *******   0.25489   0.23048
   Y-COMP.          *******   0.17873   *******   *******   *******   1.76078   1.98776

YAW ANGLE (DEG)....    1.2       5.0       3.4       5.6       7.7      -3.8      -3.9

C.G. POSITION (M)..
   X-COMP.          0.11897   0.11410   0.12316   *******   *******   0.24345   0.21757
   Y-COMP.          -.00119   0.28638   0.66213   *******   *******   1.86149   2.06715

COEF. OF CUBIC POLYNOMIAL:    -0.1352D 00     0.1860D 03    -0.8401D 04     0.1426D 06

FROM FCNC. Y C.G. =-0.00497   0.28638   0.66480   1.02866   1.41302   1.85163 ********
   ERROR (M)...... -0.00379   0.0       0.00267 ******** ******** -0.00985 ********
   C.G. VY (M/S)  =   180.      146.      109.       80.       51.        7.
   AT T=0.0.  C.G. VY= 198.      :  WHEN  VY=0.0.  T= 0.03495  AND  Y= 1.86293

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=      0.0  B=   1.1020  ER=0.01718  EM=-0.0230  CD=  2.3509

   ALL STATIONS   A=  2150.0  B=   0.6267  ER=0.00629  EM=-0.0099
```

SHOT 27 (1-03-77 ,NO. 5)

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DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=117. M/S
SOLID STEP TIER PROJECTILE ; MASS=0.5150 KG  LENGTH=0.219 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)...... 0.00070   0.00251   0.00551   0.00940   0.01543   0.03171   *******

NOSE POSITION (M)..
   X-COMP.           0.11702   0.11574   0.12131   0.13200   0.13320   *******   *******
   Y-COMP.           0.12526   0.42467   0.81019   1.16747   1.55164   *******   *******

TAIL POSITION (M)..
   X-COMP.           *******   0.10999   0.11992   0.12229   0.13256   0.11885   0.10659
   Y-COMP.           *******   0.20663   0.59543   0.95185   1.32381   1.92403   2.10480

YAW ANGLE (DEG)....    0.6       1.1       0.4      -0.5      -0.6      -1.2      -0.9

C.G. POSITION (M)..
   X-COMP.           0.11468   0.11280   0.12060   0.12704   0.13287   0.11455   0.10341
   Y-COMP.           0.01342   0.31330   0.70049   1.05733   1.43527   2.03108   2.21189

COEF. OF CUBIC POLYNOMIAL:     -0.1008D 00    0.1779D 03   -0.6618D 04    0.9865D 05

FROM POLY. Y C.G. =-0.01416    0.30181   0.70049   1.07761   1.48331   2.02478 ********
   ERROR (M)....... -0.02758 -0.01149   0.0       0.02028   0.04804 -0.00630 ********
   C.G. VY (M/S)  =    197.      156.      114.       83.       54.       17.
   AT T=0.0.  C.G. VY= 219.       ;  WHEN  VY=0.0,  T= 0.04276  AND  Y= 2.11586

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0   B=   0.8369  ER=0.00603  EM=-0.0092   CD=  1.7841
   STATIONS 2-5    A=      0.0   B=   0.8793  ER=0.00930  EM=-0.0112   CD=  1.8744
   STATIONS 3-6    A=      0.0   B=   0.7950  ER=0.05836  EM=-0.0647   CD=  1.6948
   ALL STATIONS    A=      0.0   B=   0.9880  ER=0.05599  EM=-0.1020   CD=  2.1061

   STATIONS 1-4    A=   2407.3   B=   0.6819  ER=0.00369  EM=-0.0059
   STATIONS 2-5    A=   2348.0   B=   0.6549  ER=0.00213  EM=-0.0034
   STATIONS 3-6    A=   1929.4   B=   0.4508  ER=0.02652  EM=-0.0339
   ALL STATIONS    A=   1460.1   B=   0.6979  ER=0.02703  EM= 0.0480
```

SHOT 28 (1-03-77 ,NO. 6)

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DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=116. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5415 KG  LENGTH=0.225 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00067   0.00247   0.00546   0.00937   0.01543   0.03183   *******

NOSE POSITION (M)..
   X-COMP.          0.10492   0.10327   0.10578   0.10535   0.07490   *******   *******
   Y COMP.          0.11173   0.40869   0.80063   1.17654   1.59290   *******   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.09996   0.12095   0.12755   0.11428   0.02499   *******
   Y COMP.          *******   0.16993   0.57292   0.94897   1.35357   2.01881   *******

YAW ANGLE (DEG)....   0.5       0.6      -4.6      -8.5     -12.0      -5.1       0.0

C.G. POSITION (M)..
   X COMP.          0.10315   0.10162   0.11337   0.11645   0.09459   0.00526   *******
   Y COMP.          -.00076   0.28931   0.68677   1.06276   1.47324   2.12957   *******

COEF. OF CUBIC POLYNOMIAL:     -0.1119D 00    0.1758D 03    -0.6098D 04    0.8762D 05

FROM PONC. Y C.G. = 0.02681   0.28318   0.68677   1.07943   1.51197   2.12454 ********
   ERROR (M)......  0.02605   0.00613   0.0       0.01667   0.03874 -0.00503 ********
   C.G. VY (M/S)  =   192.      156.      117.      87.       59.       21.
   AT T=0.0.  C.G. VY= 210.     :  WHEN  VY=0.0.  T= 0.04651  AND  Y= 2.27355

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=     0.0   B=  0.7109  ER=0.00701  EM=-0.0094  CD=  1.5934
   STATIONS 2-5    A=     0.0   B=  0.7919  ER=0.00735  EM=-0.0086  CD=  1.7749
   STATIONS 3-6    A=     0.0   B=  0.7103  ER=0.05800  EM=-0.0631  CD=  1.5921
   ALL STATIONS    A=     0.0   B=  0.8876  ER=0.04540  EM=-0.0878  CD=  1.9895

   STATIONS 1-4    A=  2261.0   B=  0.5634  ER=0.00497  EM=-0.0066
   STATIONS 2-5    A=  2261.0   B=  0.5883  ER=0.00306  EM= 0.0045
   STATIONS 3-6    A=  2261.0   B=  0.2493  ER=0.13841  EM= 0.2140
   ALL STATIONS    A=  2261.0   B=  0.5000  ER=0.04113  EM=-0.0765

   STATIONS 1-4    A=  3884.9   B=  0.4669  ER=0.00382  EM=-0.0051
   STATIONS 2-5    A=  2558.3   B=  0.5690  ER=0.00315  EM= 0.0044
   STATIONS 3-6    A=  1997.4   B=  0.3905  ER=0.02547  EM=-0.0331
   ALL STATIONS    A=  1340.4   B=  0.6335  ER=0.02245  EM= 0.0387
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                                SHOT   30 ( 2-03-77 .NO. 1)

        DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=115. M/S
        SOLID FLAT NOSE PROJECTILE : MASS=0.5425 KG  LENGTH=0.225 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00070   0.00248   0.00549   0.00937   0.01546   0.03168   *******

NOSE POSITION (M)..
   X-COMP.          0.10339   0.10370   0.11499   0.13724   0.16000   *******   *******
   Y-COMP.          0.12086   0.41282   0.79573   1.16234   1.57325   *******   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.08852   *******   0.10590   0.13747   *******   0.16934
   Y-COMP.          *******   0.17136   *******   0.92709   1.34115   *******   2.06590

YAW ANGLE (DEG)....   1.4       2.6       2.1       5.9       5.8       2.5       1.3

C.G. POSITION (M)..
   X-COMP.          0.09789   0.09611   0.10695   0.12157   0.14874   *******   0.17444
   Y-COMP.          0.00849   0.29209   0.68352   1.04472   1.45720   *******   2.17828

COEF. OF CUBIC POLYNOMIAL:    -0.1183D 00    0.1856D 03    -0.8306D 04    0.1870D 06

FROM PONC. Y C.G. =-0.00045   0.29583   0.68352   1.05050   1.43867   1.82604 ********
   ERROR (M)...... -0.00894   0.00374   0.0       0.00579 -0.01853 ******** ********
   C.G. VY (M/S)  =   184.      150.      111.      80.       50.       2.
   AT T=0.0. C.G. VY= 202.      ;  WHEN  VY=0.0.  T= 0.03245  AND  Y= 1.82678

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=     0.0  B=  0.8003  ER=0.01534  EM=-0.0206  CD=  1.7971

   ALL STATIONS   A=  2261.0  B=  0.5904  ER=0.00584  EM= 0.0087

   ALL STATIONS   A=  2482.2  B=  0.6126  ER=0.01085  EM=-0.0185
```

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                      SHOT   31 ( 2-03-77 ,NO. 2)

   DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY= 99. M/S
   SOLID FLAT NOSE PROJECTILE ; MASS=0.5430 KG  LENGTH=0.225 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECCNDS)..... 0.00070   0.00250   0.00550   0.00938   0.01547   0.03177   *******

NCSE POSITICN (M)..
   X-CCMP.          0.11326   0.11296   0.12559   0.15618   0.19669   *******   *******
   Y-COMP.          0.12136   0.41077   0.79339   1.16201   1.57323   *******   *******

TAIL POSITICN (M)..
   X-COMP.          *******   0.09533   *******   *******   0.14428   0.24082   0.24030
   Y-CCMP.          *******   0.17287   *******   *******   1.33072   1.92901   2.03543

YAW ANGLE (DEG)....    1.5       3.6       3.8       4.8      11.2       0.2       0.5

C.G. PCSITICN (M)..
   X-COMP.          0.10757   0.10415   0.11071   0.13742   0.17049   0.24141   0.24207
   Y-CCMP.          0.00900   0.29182   0.68188   1.05109   1.45198   2.04151   2.14792

COEF. OF CUBIC POLYNOMIAL:    -0.1056D 00    0.1723D 03    -0.5911D 04    0.8232D 05

FRCM PCNC. Y C.G. =-0.01569   0.28678   0.68188   1.06486   1.48711   2.03707 ********
   ERROR (M)....... -0.02470 -0.00504   0.0       0.01378   0.03514 -0.00444 ********
   C.G. VY (M/S)  =    186.      152.      115.       85.       56.       16.
   AT T=0.C.  C.G. VY= 203.      ;  WHEN  VY=0.0.   T= 0.04008  AND  Y= 2.10605

FORCELET CCEFFICIENTS BASED ON :

   STATICNS 1-4    A=     0.0  B=  0.7007  ER=0.00700  EM=-0.0092  CD=  1.5750
   STATIONS 2-5    A=     0.0  B=  0.8013  ER=0.00912  EM=-0.0116  CD=  1.9011
   STATICNS 3-6    A=     0.0  B=  0.7774  ER=0.06454  EM=-0.0675  CD=  1.7473
   ALL STATIONS    A=     0.0  B=  0.9491  ER=0.05671  EM=-0.1062  CD=  2.1333

   STATICNS 1-4    A=  2261.0  B=  0.5480  ER=0.00505  EM=-0.0065
   STATICNS 2-5    A=  2261.0  B=  0.5891  ER=0.00189  EM=-0.0029
   STATICNS 3-6    A=  2261.0  B=  0.3935  ER=0.02268  EM=-0.0286
   ALL STATIONS    A=  2261.0  B=  0.5000  ER=0.02491  EM= 0.0484

   STATICNS 1-4    A=  4483.3  B=  0.4120  ER=0.00385  EM=-0.0046
   STATICNS 2-5    A=  3041.9  B=  0.5306  ER=0.00351  EM=-0.0050
   STATICNS 3-6    A=  2224.2  B=  0.3990  ER=0.02266  EM=-0.0288
   ALL STATIONS    A=  1715.2  B=  0.6101  ER=0.02039  EM= 0.0351
```

SHOT 32 (2-03-77 ,NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=152. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5415 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00075	0.00255	0.00556	0.00943	0.01547	0.03177	*******
NOSE POSITION (M)..							
X-COMP.	*******	0.11733	0.13460	0.17590	0.22202	0.24111	*******
Y-COMP.	*******	0.41777	0.80164	1.17095	1.57249	2.10010	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.09542	0.09659	0.11385	0.16676	*******	0.23247
Y-COMP.	*******	0.17909	0.57774	0.93740	1.34446	*******	2.00860
YAW ANGLE (DEG)....	1.4	4.3	8.4	11.0	13.7	0.5	-0.5
C.G. POSITION (M)..							
X-COMP.	*******	0.10638	0.11560	0.14488	0.19439	0.23915	0.23070
Y-COMP.	*******	0.29843	0.68969	1.05418	1.45848	1.98762	2.12109

COEF. OF CUBIC POLYNOMIAL: -0.8821D-01 0.1661D 03 -0.5336D 04 0.6811D 05

FROM PONC. Y C.G. =	0.01487	0.29793	0.68031	1.05418	1.46803	1.98135	********
ERROR (M)......	********	-0.00050	-0.00938	0.0	0.00956	-0.00627	********
C.G. VY (M/S) =	173.	145.	112.	84.	55.	12.	

AT T=0.0. C.G. VY= 188. ; WHEN VY=0.0. T= 0.03735 AND Y= 2.01359

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS	A= 0.0	B= 0.9928	ER=0.08000	EM= 0.1237	CD= 2.2254
ALL STATIONS	A= 2261.0	B= 0.5000	ER=0.01190	EM=-0.0183	
ALL STATIONS	A= 2060.8	B= 0.5481	ER=0.00740	EM= 0.0096	

```
                          SHOT   33 ( 2-03-77 .NO. 4)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=153. M/S
      SOLID FLAT NOSE PROJECTILE ; MASS=0.5425 KG   LENGTH=0.225 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS).....  0.00071   0.00250   0.00550   0.00939   0.01549   0.03180   *******

NOSE POSITION (M)..
   X-COMP.           0.10576   0.11123   0.12231   0.14453   0.16640   *******   *******
   Y-COMP.           0.12174   0.41739   0.80189   1.16589   1.57246   *******   *******

TAIL POSITION (M)..
   X-COMP.           *******   0.09956   *******   0.11817   0.14673   *******   0.18117
   Y-COMP.           *******   0.18252   *******   0.94427   1.32850   *******   1.71637

YAW ANGLE (DEG)....    0.9       2.1       1.5       4.3       3.6      -1.4      -1.9

C.G. POSITION (M)..
   X-COMP.           0.10623   0.10540   0.11662   0.13135   0.15657   *******   0.17391
   Y-COMP.           0.00930   0.29996   0.68953   1.05508   1.45048   *******   1.82864

COEF. OF CUBIC POLYNOMIAL:     -0.1194D 00    0.1873D 03   -0.8286D 04    0.1766D 06

FROM FONC. Y C.G. = 0.00591   0.30129   0.68953   1.05801   1.42463   1.55560 ********
   ERROR (M)...... -0.00338   0.00133   0.0       0.00293  -0.02585 ******** ********
   C.G. VY (M/S)  =   181.      150.      112.       79.       43.     *****
   AT T=0.0.  C.G. VY= 197.      ;  WHEN  VY=0.0.  T= 0.02557  AND  Y= 1.63516

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=     0.0  B=   0.8220  ER=0.02278  EM= 0.0341  CD=  1.8457

   ALL STATIONS   A=  2261.0  B=   0.6214  ER=0.00643  EM=-0.0087

   ALL STATIONS   A=  4000.0  B=   0.5000  ER=0.01314  EM=-0.0259
```

SHOT 34 (2-03-77 .NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID STEP TIER PROJECTILE ; MASS=0.5620 KG LENGTH=0.233 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00070	0.00250	0.00550	0.00938	0.01549	0.03180	*******
NOSE POSITION (M)..							
X-COMP.	0.10932	0.10951	0.11357	0.11789	0.08509	*******	*******
Y-COMP.	0.11061	0.40059	0.78011	1.15038	1.55114	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.11045	*******	0.13491	*******	0.03389	*******
Y-COMP.	*******	0.16763	*******	0.91324	*******	1.93035	*******
YAW ANGLE (DEG)....	0.1	-1.1	-3.0	-8.8	-7.9	-3.7	-0.7
C.G. POSITION (M)..							
X-COMP.	0.10890	0.10999	0.12579	0.12658	0.11727	0.01920	*******
Y-COMP.	-.00831	0.28169	0.66182	1.02935	1.43666	2.04348	*******

COEF. OF CUBIC POLYNOMIAL: -0.1183D 00 0.1707D 03 -0.5810D 04 0.8114D 05

FROM PONC. Y C.G. =	-0.02977	0.26957	0.66182	1.04372	1.46950	2.03930	********
ERROR (M)......	-0.02146	-0.01212	0.0	0.01437	0.03284	-0.00418	********
C.G. VY (M/S) =	184.	151.	114.	85.	57.	18.	

AT T=0.0, C.G. VY= 201. ; WHEN VY=0.0, T= 0.04254 AND Y= 2.13221

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.7598	ER=0.00294	EM=-0.0049	CD= 1.7674
STATIONS 2-5	A= 0.0	B= 0.7644	ER=0.00836	EM=-0.0109	CD= 1.7782
STATIONS 3-6	A= 0.0	B= 0.7550	ER=0.05859	EM=-0.0611	CD= 1.7563
ALL STATIONS	A= 0.0	B= 0.9268	ER=0.05068	EM=-0.0944	CD= 2.1561

STATIONS 1-4	A= 1936.5	B= 0.6259	ER=0.00140	EM=-0.0023
STATIONS 2-5	A= 2136.7	B= 0.5643	ER=0.00156	EM=-0.0027
STATIONS 3-6	A= 2086.4	B= 0.3982	ER=0.01935	EM=-0.0242
ALL STATIONS	A= 1580.3	B= 0.6119	ER=0.01954	EM= 0.0328

SHOT 35 (11-04-77 ,NO. 0)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3668 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00050	0.00211	0.00533	0.00947	0.01550	0.03208	*******
NOSE POSITION (M)..							
X-COMP.	0.13476	*******	*******	*******	*******	*******	0.11442
Y-COMP.	0.09733	*******	*******	*******	*******	*******	1.71396
TAIL POSITION (M)..							
X-COMP.	*******	0.12827	0.13539	*******	*******	*******	0.13010
Y-COMP.	*******	0.21997	0.60684	*******	*******	*******	1.55857
YAW ANGLE (DEG)....	1.0	1.0	2.1	0.0	0.0	0.0	-2.7
C.G. POSITION (M)..							
X-COMP.	0.13211	0.13079	0.14096	*******	*******	*******	0.12226
Y-COMP.	0.02138	0.29593	0.68264	*******	*******	*******	1.63627

```
                                SHOT   37 (12-04-77 ,NO. 1)

         DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=127. M/S
         SOLID FLAT NOSE PROJECTILE ; MASS=0.3677 KG  LENGTH=0.152 M

X-RAY STATION......     NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00048   0.00189   0.00512   0.02949   0.05000   0.05000   *******

NOSE POSITION (M)..
   X-COMP.          0.12032   0.11791   0.11926   0.07960   *******   *******   0.07542
   Y-COMP.          0.09254   0.33842   0.72707   1.29362   *******   *******   1.30080

TAIL POSITION (M)..
   X-COMP.          *******   0.11879   0.13316   0.15676   *******   *******   0.15877
   Y-COMP.          *******   0.17684   0.56088   1.16190   *******   *******   1.16232

YAW ANGLE (DEG)....   0.0      -0.3      -2.8     -15.3       0.0       0.0     -16.2

C.G. POSITION (M)..
   X-COMP.          0.12032   0.11835   0.12621   0.11818   *******   *******   0.11710
   Y-COMP.          0.01654   0.25763   0.64398   1.22776   *******   *******   1.23156

COEF. OF CUBIC POLYNOMIAL:    -0.76790-01     0.2000D 03    -0.1288D 05     0.2577D 06

FROM FCNC. Y C.G. = 0.02029   0.25763   0.67356   1.22277 -4.63386 -4.63386 ********
   ERROR (M).......  0.00375   0.0       0.02958 -0.00499 ******** ******** ********
   C.G. VY (M/S)  =    183.      154.      108.     *****     *****     *****
   AT T=0.0.  C.G. VY= 195.      ;  WHEN  VY=0.0.  T= 0.02103  AND  Y= 1.41116

FORCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=      0.0  B=  2.4370  ER=0.05535  EM=-0.0689  CD=  3.7092

   ALL STATIONS   A=   5081.8  B=  0.5525  ER=0.01746  EM= 0.0296
```

SHOT 38 (12-04-77 ,NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=124. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3680 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS)......	0.00048	0.00189	0.00509	0.01368	0.05000	0.05000	*******
NOSE POSITION (M)..							
X-COMP.	0.13701	0.13821	0.16419	0.25477	*******	*******	*******
Y COMP.	0.10013	0.34282	0.72749	1.25735	*******	*******	*******
TAIL POSITION (M)..							
X COMP.	*******	0.12146	*******	*******	0.23793	*******	0.22974
Y-COMP.	*******	0.19177	*******	*******	1.62423	*******	1.63854
YAW ANGLE (DEG)....	1.5	3.2	7.1	8.0	-1.4	0.0	-1.8
C.G. POSITION (M)..							
X COMP.	0.13316	0.12984	0.14555	0.23395	0.23435	*******	0.22497
Y-COMP.	0.02423	0.26730	0.65381	1.18426	1.70015	*******	1.71419

COEF. OF CUBIC POLYNOMIAL: -0.5085D-91 0.17520 03 -0.7493D 04 0.9380D 05

FROM PONC. Y C.G. =	-0.01727	0.23823	0.65381	1.28034	1.69768	1.69768	********
ERROR (M).......	0.04150	-0.02906	0.0	0.09608	-0.00246	********	********
C.G. VY (M/S) =	205.	160.	106.	50.	*****	*****	

AT T=0.0. C.G. VY= 225. ; WHEN VY=0.0. T= 0.03832 AND Y= 1.80046

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.5164 ER=0.22262 EM= 0.3436 CD= 2.3098

ALL STATIONS A= 1461.3 B= 0.9061 ER=0.05433 EM= 0.0961

```
                              SHOT   39 ( 12-04-77 ,NO. 3)

        DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=195. M/S
        SOLID STEP TIER PROJECTILE ; MASS=0.3715 KG  LENGTH=0.159 M

X-RAY STATION......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00049  0.00189  0.00561  0.01051  0.02599  0.05000  *******

NOSE POSITION (M)..
   X-COMP.          0.13335  0.13664  0.17887  0.24232  *******  *******  0.23332
   Y-COMP.          0.07129  0.32456  0.76214  1.09473  *******  *******  1.24152

TAIL POSITION (M)..
   X-COMP.          *******  0.11650  0.13496  *******  *******  *******  *******
   Y-COMP.          *******  0.18838  0.61338  *******  *******  *******  *******

YAW ANGLE (DEG)....   2.0      1.9      8.6     11.9      0.0      0.0     -4.4

C.G. POSITION (M)..
   X-COMP.          0.12778  0.12627  0.15626  0.20929  *******  *******  0.24570
   Y-COMP.          -.01038  0.25445  0.68556  1.01983  *******  *******  1.16061

COEF. OF CUBIC POLYNOMIAL:   -0.1216D 00    0.2356D 03   -0.2120D 05    0.8675D 06

FROM PONC. Y C.G. =-0.02205  0.25445  0.69460  1.01707  1.38498  0.83170 ********
   ERROR (M)....... -0.01167  0.0      0.00905 -0.00276 ******** ******** ********
   C.G. VY (M/S)  =    239.     165.      87.      49.       5.     *****
   AT T=0.0.  C.G. VY= 284.     :  WHEN  VY=0.0.  T= 0.02868  AND  Y= 1.39196

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=     0.0  B=   1.4666  ER=0.01003  EM=-0.0165  CD=  2.2552

   ALL STATIONS   A=  1926.7  B=   1.3010  ER=0.00867  EM=-0.0117
```

SHOT 41 (12-04-77 .NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=106. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.4968 KG LENGTH=0.206 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00048	0.00187	0.00547	0.00938	0.01547	0.03202	*******
NOSE POSITION (M)..							
X COMP.	0.12087	0.11712	0.12132	0.12092	*******	0.02005	*******
Y-COMP.	0.08420	0.33020	0.80190	1.15042	*******	2.01870	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.12315	*******	0.13509	*******	*******	0.00234
Y COMP.	*******	0.43220	*******	0.94194	*******	*******	2.00904
YAW ANGLE (DEG)....	0.6	-1.3	-2.8	-8.7	0.0	-2.8	0.0
C.G. POSITION (M)..							
X-COMP.	0.11853	0.12014	0.13119	0.12801	*******	0.02992	0.00252
Y COMP.	.01877	0.38120	0.69937	1.04618	*******	1.91617	2.11204

COEF. OF CUBIC POLYNOMIAL: -0.60590-01 0.20760 03 -0.11910 05 0.22980 06

FROM PONC. Y C.G. =	0.02785	0.26467	0.69937	1.02214	1.37282	1.91738	********
ERROR (M).......	0.04662	-0.11653	0.0	-0.02404	********	0.00121	********
C.G. VY (M/S) =	191.	151.	98.	70.	48.	23.	

AT T=0.0. C.G. VY= 209. ; WHEN VY=0.0. T= 0.07270 AND Y= 2.31533

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.0854 ER=0.06573 EM=-0.1257 CD= 2.2320

ALL STATIONS A= 422.2 B= 0.9703 ER=0.06390 EM=-0.1165

```
SHOT   42 (12-04-77 .NO. 6)

DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=121. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.4965 KG   LENGTH=0.206 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00048   0.00188   0.00548   0.00939   0.01550   0.03208   *******

NOSE POSITION (M)..
   X-COMP.          0.17917   0.17794   0.18430   0.20730   0.22815   0.22480   *******
   Y-COMP.          0.08387   0.33870   0.81906   1.18429   1.56587   2.10855   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.17870   0.18474   0.17988   0.21048   *******   0.22959
   Y-COMP.          *******   0.11321   0.58996   0.96923   1.35714   *******   2.05716

YAW ANGLE (DEG)....   -0.2      0.2       5.4       4.4       4.4      -[illegible].2     -2.8

C.G. POSITION (M)..
   X-COMP.          0.17571   0.17832   0.18452   0.19359   0.21932   0.23252   0.21972
   Y-COMP.          -.01913   0.22596   0.70451   1.07676   1.46651   2.00584   2.15969

COEF. OF CUBIC POLYNOMIAL:    -0.94890-01     0.1771D 03    -0.6309D 04    0.8818D 05

FROM PONC. Y C.G. =-0.04108   0.20833   0.70451   1.09263   1.50983   2.00060 ********
   ERROR (M)...... -0.02195 -0.01763   0.0       0.01587   0.04333 -0.00524 ********
   C.G. VY (M/S)  =   194.      165.      116.      8[illegible].       55.        9.
   AT T=0.C.   C.G. VY= 206.      :  WHEN   VY=0.0,  T= 0.03632  AND  Y= 2.0198[illegible]

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0   B=   0.7899  ER=0.00211  EM=-0.0036  CD=  1.6233
   STATIONS 2-5    A=      0.0   B=   0.7711  ER=0.01585  EM=-0.0198  CD=  1.5846
   STATIONS 3-6    A=      0.0   B=   0.8137  ER=0.08301  EM=-0.0855  CD=  1.6722
   ALL STATIONS    A=      0.0   B=   0.9874  ER=0.08389  EM=-0.1360  CD=  2.0293

   STATIONS 1-4    A=   1567.8   B=   0.6952  ER=0.00179  EM=-0.0022
   STATIONS 2-5    A=   3084.3   B=   0.5086  ER=0.00306  EM=-0.0047
   STATIONS 3-6    A=   2492.1   B=   0.4011  ER=0.02431  EM=-0.0301
   ALL STATIONS    A=   2124.3   B=   0.5920  ER=0.02429  EM= 0.0433
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                                   SHOT   43 ( 13-04-77 .NO. 1)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=110. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.3661 KG  LENGTH=0.152 M

X-RAY STATION......     NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00054   0.00193   0.00564   0.01056   0.02613   0.05000   *******

NOSE POSITION (M)..
   X-COMP.          0.15762   0.15547   0.16364   0.18113   *******   *******   0.22081
   Y-COMP.          0.09051   0.33419   0.76729   1.11139   *******   *******   1.75551

TAIL POSITION (M)..
   X-COMP.          *******   0.15135   0.16560   0.17080   *******   *******   *******
   Y-COMP.          *******   0.18123   0.59738   0.95508   *******   *******   *******

YAW ANGLE (DEG)....   0.3       1.0       7.4       3.1       0.0       0.0       0.2

C.G. POSITION (M)..
   X-COMP.          0.15682   0.15341   0.16712   0.17597   *******   *******   0.22041
   Y-COMP.          0.01451   0.25771   0.68234   1.03324   *******   *******   1.67951

COEF. OF CUBIC POLYNOMIAL:    -0.9597D-01     0.2148D 03    -0.1751D 05     0.6906D 06

FROM PONC. Y C.G. = 0.01122   0.25771   0.69525   1.03387   1.35787 -0.20281 ********
   ERROR (M)....... -0.00330  0.0       0.01291   0.00064 ******** ******** ********
   C.G. VY (M/S)  =    204.     155.      90.       52.     *****     *****
   AT T=0.0.   C.G. VY= 232.     ;  WHEN  VY=0.0.   T= 0.02480  AND   Y= 1.36041

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=      0.0  B=  1.3010  ER=0.00615  EM=-0.0094  CD=  1.9716

   ALL STATIONS    A=   2877.5  B=  1.0234  ER=0.00770  EM= 0.0129
```

SHOT 44 (13-04-77 ,NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=173. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3677 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00054	*******	*******	0.01057	0.02612	*******	*******
NOSE POSITION (M)..							
X-COMP.	0.13756	*******	*******	0.11103	0.07814	*******	*******
Y-COMP.	0.08144	*******	*******	1.09652	1.59384	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	*******	0.10453	*******	*******
Y-COMP.	*******	*******	*******	*******	1.44992	*******	*******
YAW ANGLE (DEG)....	0.3	0.0	0.0	-4.2	-11.3	0.0	0.0
C.G. POSITION (M)..							
X-COMP.	0.13690	*******	*******	0.12200	0.09134	*******	*******
Y-COMP.	0.00544	*******	*******	1.02132	1.52188	*******	*******

SHOT 46 (13-04-77 .NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=117. M/S
SOLID STEP TIER PROJECTILE ; MASS=0.3714 KG LENGTH=0.159 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00054	0.00193	0.00566	0.01056	0.02615	*******	*******
NOSE POSITION (M)..							
X-COMP.	0.13498	0.13445	0.14897	*******	*******	*******	0.17426
Y-COMP.	0.09215	0.34809	0.79844	*******	*******	*******	1.25694
TAIL POSITION (M)..							
X-COMP.	*******	0.13151	0.15259	0.15090	*******	*******	*******
Y-COMP.	*******	0.18958	0.63873	0.98740	*******	*******	*******
YAW ANGLE (DEG)....	0.6	0.5	3.0	1.6	0.0	0.0	3.9
C.G. POSITION (M)..							
X-COMP.	0.13312	0.13294	0.15083	0.15521	*******	*******	0.16329
Y-COMP.	0.01031	0.26649	0.71622	1.06442	*******	*******	1.17582

COEF. OF CUBIC POLYNOMIAL: -0.1047D 00 0.2232D 03 -0.1744D 05 0.6430D 06

FROM PONC. Y C.G. =	0.00328	0.26649	0.72215	1.06849	1.41864	-0.12265	********
ERROR (M)......	-0.00703	0.0	0.00593	0.00406	********	********	********
C.G. VY (M/S) =	219.	163.	93.	53.	*****	*****	

AT T=0.0. C.G. VY= 251. ; WHEN VY=0.0. T= 0.02560 AND Y= 1.41905

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.2925 ER=0.00803 EM=-0.0134 CD= 1.9870

ALL STATIONS A= 2739.9 B= 1.0450 ER=0.00581 EM=-0.0070

```
                              SHOT   48 ( 9-05-77 ,NO. 1)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.3671 KG  LENGTH=0.152 M

X-RAY STATION......     NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00054   0.00193   0.00563   0.01052   0.02612   0.05065   *******

NOSE POSITION (M)..
   X-COMP.          0.13453   *******   0.15092   *******   *******   *******   0.13385
   Y-COMP.          0.09851   *******   0.79184   *******   *******   *******   1.31289

TAIL POSITION (M)..
   X-COMP.          *******   0.13177   0.14270   0.15194   *******   *******   0.23357
   Y-COMP.          *******   0.19960   0.64021   0.99470   *******   *******   1.19172

YAW ANGLE (DEG)....   0.6       0.5       0.1      -0.5       0.0       0.0     -21.0

C.G. POSITION (M)..
   X-COMP.          0.13281   0.13323   0.14681   0.15061   *******   *******   0.18371
   Y-COMP.          0.02253   0.27559   0.71603   1.07069   *******   *******   1.25231

COEF. OF CUBIC POLYNOMIAL:    -0.9130D-01     0.2211D 03    -0.1757D 05    0.6700D 06

FROM PONC. Y C.G. = 0.01497   0.27559   0.72062   1.06345   1.45150   0.63538 ********
   ERROR (M)...... -0.00756   0.0       0.00459 -0.00724 ******** ******** ********
   C.G. VY (M/S)  =   218.      161.       92.       53.        4.     *****
   AT T=0.0.  C.G. VY= 251.     :  WHEN  VY=0.0.  T= 0.02770  AND  Y= 1.45437

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=      0.0  B=   1.2727  ER=0.00666  EM=-0.0113  CD=  1.9338

   ALL STATIONS    A=   2291.7  B=   1.1007  ER=0.00660  EM=-0.0076
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                              SHOT  49 ( 9-05-77 ,NO. 2)

        DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=330. M/S
        SOLID FLAT NOSE PROJECTILE : MASS=0.3669 KG  LENGTH=0.152 M

X-RAY STATICN......   NC.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECCNDS)..... C.00048   0.00188   0.00559   0.01047   0.02629   0.05065   *******

NOSE POSITION (M)..
   X-COMP.          0.14058   0.14500   0.20079   *******   *******   *******   0.20027
   Y-COMP.          0.09541   0.34974   0.79023   *******   *******   *******   1.29096

TAIL POSITICN (M)..
   X-CCMF.          *******   0.11638   0.14456   0.21005   *******   *******   0.25442
   Y-COMP.          *******   0.19952   0.63286   0.97499   *******   *******   1.15975

YAW ANGLE (DEG)....   1.7       5.7      18.9       6.6       0.0       0.0     -12.4

C.G. POSITION (M)..
   X-CCMF.          0.13621   0.13069   0.17268   0.22740   *******   *******   0.22735
   Y-COMP.          0.01954   0.27463   0.71155   1.04898   *******   *******   1.22536

COEF. OF CLBIC POLYNCMIAL:    -0.82080-01    0.22090 03    -0.1794D 05    0.6845D 06

FRCM FONC. Y C.G. = 0.01138   0.27463   0.71744   1.05021   1.39767  0.20768 ********
   ERROR (M)...... -0.00816   0.0       0.00589   0.00123 ******** ******** ********
   C.G. VY (M/S)  =   220.      161.       90.       51.     *****     *****
   AT T=0.0.  C.G. VY= 252.     ;  WHEN  VY=0.0.  T= 0.02607  AND  Y= 1.39773

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=     0.0  B=  1.3572  ER=0.00827  EM=-0.0140  CD=  2.0612

   ALL STATIONS   A=  2501.9  B=  1.1297  ER=0.00585  EM=-0.0082
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                          SHCT   50 ( 9-05-77 ,NO. 3)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPRUACH VELOCITY=216. M/S
      SOLID FLAT NOSE PROJECTILE : MASS=0.3669 KG  LENGTH=0.152 M

X-RAY STATICN......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECCNDS)..... 0.00054  0.00194  0.00564  0.01053  0.02630  0.05031  *******

NOSE POSITICN (M)..
   X-COMP.          0.14683  0.14565  0.15332  *******  -.05887  *******  *******
   Y-COMP.          0.09923  0.34913  0.79151  *******  1.71421  *******  *******

TAIL POSITICN (M)..
   X-CCMP.          *******  0.14537  -.03949  0.15717  *******  *******  0.12322
   Y-COMP.          *******  0.19197  0.63576  0.97349  *******  *******  1.64306

YAW ANGLE (DEG)....   -0.1     0.2     -1.0     -1.4     -1.3      0.0     -1.0

C.G. POSITICN (M)..
   X-COMP.          0.14710  0.14551  0.05691  0.15359  -.05542  *******  0.12070
   Y-COMP.          0.02323  0.27055  0.71364  1.04941  1.63829  *******  1.71902

COEF. OF CUBIC POLYNOMIAL:    -0.7283D-01     0.1916D 03    -0.1028D 05    0.2080D 06

FRCM FCNC. Y C.G. = 0.01989  0.26581  0.71364  1.08442  1.63662  1.63442 ********
   ERROR (M)...... -0.00334 -0.00474  0.0      0.03501 -0.00166 ******** ********
   C.G. VY (M/S)  =   200.     155.      95.      60.      17.    *****
   AT T=0.0.  C.G. VY= 225.     ;  WHEN  VY=0.0.  T= 0.03824  AND  Y= 1.73734

FCNCELET CCEFFICIENTS BASED ON :

   ALL STATIONS   A=      0.0  B=  1.2468  ER=0.04995  EM= 0.0707  CD=  1.8934

   ALL STATIONS   A=   1366.4  B=  0.9913  ER=0.01776  EM= 0.0350
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SHOT   51 ( 9-05-77 .NO. 4)

DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3670 KG  LENGTH=0.152 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00051   0.00192   0.00560   0.01041   0.02623   0.05031   *******

NOSE POSITION (M)..
   X-COMP.          0.15835   *******   0.15822   0.15883   0.11864   0.09798   0.09846
   Y-COMP.          0.09866   *******   0.31313   1.16945   1.63948   1.84144   1.85421

TAIL POSITION (M)..
   X-COMP.          *******   0.15454   -.03879   0.16282   0.14566   *******   *******
   Y-COMP.          *******   0.21430   0.66467   1.01214   1.49131   *******   *******

YAW ANGLE (DEG)....   -0.2      0.1      -1.6      -5.2      -11.6     -2.3      -1.8

C.G. POSITION (M)..
   X-COMP.          0.15888   0.15481   0.05972   0.16083   0.13215   0.10394   0.10310
   Y-COMP.          0.02266   0.29030   0.73890   1.09030   1.56540   1.76567   1.77835

COEF. OF CUBIC POLYNOMIAL:     -0.2121D-01     0.1569D 03     -0.5062D 04     0.5270D 05

FROM PONC. Y C.G. =-0.06566   0.23409   0.73890   1.13477   1.72053   1.73916 ********
   ERROR (M)...... -0.08832 -0.05621   0.0       0.04447   0.15513 -0.02651 ********
   C.G. VY (M/S)   =   250.      182.      105.       65.       18.      *****
   AT T=0.C.   C.G. VY= 287.      ;  WHEN  VY=0.0.   T= 0.03880   AND   Y= 1.83230

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0  B=   1.3097  ER=0.00824  EM=-0.0140  CD=  1.9896
   STATIONS 2-5    A=      0.0  B=   1.3542  ER=0.04861  EM=-0.0665  CD=  2.0572
   STATIONS 3-6    A=      0.0  B=   1.2922  ER=0.16323  EM=-0.1888  CD=  1.9530
   ALL STATIONS    A=      0.0  B=   1.4289  ER=0.24066  EM= 0.4031  CD=  2.1707

   STATIONS 1-4    A=   2327.3  B=   1.1209  ER=0.00666  EM=-0.0087
   STATIONS 2-5    A=   2529.9  B=   0.8112  ER=0.00721  EM=-0.0117
   STATIONS 3-6    A=   1326.4  B=   0.6316  ER=0.08728  EM=-0.1040
   ALL STATIONS    A=   1361.7  B=   1.0173  ER=0.08684  EM= 0.1551
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SHOT 52 (10-05-77 ,NO. 1)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.4968 KG LENGTH=0.206 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00089	0.00248	0.00548	0.00942	0.01541	0.03196	*******
NOSE POSITION (M)..							
X-COMP.	0.16460	*******	0.16407	0.16871	*******	0.10961	*******
Y-COMP.	0.16477	*******	0.80641	1.16064	*******	2.04029	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	-.02583	0.17025	0.16798	0.12517	0.09758
Y-COMP.	*******	*******	0.59108	0.96258	1.32129	1.83556	2.16647
YAW ANGLE (DEG)....	0.0	0.0	-3.4	-5.3	-2.5	-3.5	-1.9
C.G. POSITION (M)..							
X-COMP.	0.16442	*******	0.06912	0.16948	0.15900	0.11739	0.09075
Y-COMP.	0.06177	*******	0.69875	1.06161	1.42390	1.93793	2.26924

COEF. OF CUBIC POLYNOMIAL: -0.8607D-01 0.1744D 03 -0.6351D 04 0.9004D 05

FROM FUNC. Y C.G. =	0.05633	0.31657	0.69641	1.06161	1.44321	1.91786	********
ERROR (M).......	-0.00544	********	-0.00233	0.0	0.01931	-0.02007	********
C.G. VY (M/S) =	180.	148.	109.	79.	51.	11.	

AT T=0.0. C.G. VY= 204. ; WHEN VY=0.0. T= 0.03790 AND Y= 1.94954

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.9591 ER=0.08965 EM= 0.1598 CD= 1.9722

ALL STATIONS A= 1780.7 B= 0.6878 ER=0.01423 EM=-0.0201

SHOT 53 (10-05-77 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=156. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5427 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00093	0.00253	0.00553	0.00943	0.01543	0.03208	*******
NOSE POSITION (M)..							
X-COMP.	0.16906	-.01796	0.18439	0.22299	0.25694	-.00415	*******
Y-COMP.	0.15948	0.42603	0.80722	1.18458	1.58099	2.10613	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	-.02468	0.16421	0.21630	0.22173	0.24253
Y-COMP.	*******	*******	0.60065	0.96820	1.37396	1.94053	2.03968
YAW ANGLE (DEG)....	0.9	1.3	7.6	10.1	7.9	0.7	-1.5
C.G. POSITION (M)..							
X-COMP.	0.16572	-.02306	0.07986	0.19360	0.23662	0.10879	0.23684
Y-COMP.	0.04703	0.31365	0.70394	1.07639	1.47748	2.02333	2.15204

COEF. OF CUBIC POLYNOMIAL: -0.1042D 00 0.1761D 03 -0.6056D 04 0.8207D 05

FROM PONC. Y C.G. =	0.02603	0.30036	0.70394	1.09266	1.50704	2.01974	********
ERROR (M).......	-0.02100	-0.01328	0.0	0.01627	0.02957	-0.00359	********
C.G. VY (M/S) =	188.	156.	117.	85.	55.	11.	

AT T=0.C. C.G. VY= 213. ; WHEN VY=0.0. T= 0.03747 AND Y= 2.04888

FONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.7923	ER=0.00277	EM=-0.0045	CD= 1.7798
STATIONS 2-5	A= 0.0	B= 0.7888	ER=0.00836	EM=-0.0105	CD= 1.7720
STATIONS 3-6	A= 0.0	B= 0.8029	ER=0.08181	EM=-0.0909	CD= 1.8035
ALL STATIONS	A= 0.0	B= 1.0143	ER=0.06683	EM=-0.1176	CD= 2.2784
STATIONS 1-4	A= 2261.0	B= 0.6548	ER=0.00310	EM=-0.0047	
STATIONS 2-5	A= 2261.0	B= 0.5800	ER=0.00178	EM=-0.0026	
STATIONS 3-6	A= 2261.0	B= 0.4025	ER=0.02738	EM=-0.0329	
ALL STATIONS	A= 2261.0	B= 0.5739	ER=0.02242	EM= 0.0308	
STATIONS 1-4	A= 2512.0	B= 0.6267	ER=0.00122	EM=-0.0018	
STATIONS 2-5	A= 2340.7	B= 0.5776	ER=0.00171	EM=-0.0025	
STATIONS 3-6	A= 2776.0	B= 0.3214	ER=0.02270	EM=-0.0299	
ALL STATIONS	A= 1957.8	B= 0.6100	ER=0.01881	EM= 0.0296	

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                              SHOT   54 (10-05-77 ,NO. 3)

          DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
          SOLID FLAT NOSE PROJECTILE ; MASS=0.5415 KG  LENGTH=0.225 M

X-RAY STATION......     NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECCNDS)..... C.0C091   0.00252   0.00552   0.00941   0.01544   0.03208   *******

NOSE PCSITICN (M)..
   X-COMP.          0.17336   -.02058   0.15659   0.13549   0.07702   *******   *******
   Y-COMP.          0.16442   0.43590   0.81599   1.18370   1.56770   *******   *******

TAIL PCSITICN (M)..
   X-COMP.          *******   *******   0.01219   0.17537   0.13898   *******   *******
   Y-COMP.          *******   *******   0.60970   0.95809   1.37267   *******   *******

YAW ANGLE (DEG)....   -1.2      -2.1     -10.1     -13.7     -17.0       0.0       0.0

C.G. POSITION (M)..
   X-COMP.          0.17807   -.01234   0.08439   0.15543   0.10800   *******   *******
   Y-COMP.          0.05202   0.32370   0.71284   1.07090   1.47019   *******   *******

COEF. OF CUBIC POLYNOMIAL:    -0.1188D 00     0.1983D 03    -0.9939D 04    0.2434D 06

FRCM FONC. Y C.G. = C.05668   0.32432   0.71284   1.07526   1.44260   1.71978 ********
   ERROR (M)....... 0.00466   0.00062   0.0       0.00437  -0.02758 ******** ********
   C.G. VY (M/S)  =   183.      151.      111.       78.       46.     *****
   AT T=0.0.  C.G. VY= 207.      ;  WHEN  VY=0.0.  T= 0.02895  AND  Y= 1.73455

PONCELET CCEFFICIENTS BASED ON :

   ALL STATIONS   A=     0.0  B=  0.6627  ER=0.01145  EM= 0.0157  CD=  1.9337

   ALL STATIONS   A=  2261.0  B=  0.6487  ER=0.00675  EM=-0.0093

   ALL STATIONS   A=  3013.0  B=  0.6124  ER=0.01416  EM=-0.0276
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SHOT  55 (10-05-77 ,NO. 4)

DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5414 KG  LENGTH=0.225 M

X-RAY STATION......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00063  0.00252  0.00553  0.00943  0.01547  0.03208  *******

NOSE POSITION (M)..
   X-COMP.          0.17596  -.00953  0.17939  0.19757  0.21742  *******  *******
   Y-COMP.          0.11793  0.46370  0.86943  1.26906  1.68533  *******  *******

TAIL POSITION (M)..
   X-COMP.          *******  0.17246  -.01681  0.15967  0.17909  0.24485  0.23931
   Y-COMP.          *******  0.23621  0.64637  1.03664  1.46668  2.07870  2.12777

YAW ANGLE (DEG)....   -0.6     0.3      1.8      5.7      7.7     -1.1     -1.6

C.G. POSITION (M)..
   X-COMP.          0.17851  0.08147  0.08129  0.17862  0.19826  0.24053  0.23323
   Y-COMP.          0.00546  0.34996  0.75790  1.15285  1.57601  2.19112  2.24011

COEF. OF CUBIC POLYNOMIAL:   -0.1005D 00    0.1886D 03   -0.6654D 04    0.9354D 05

FROM PONC. Y C.G. =-0.01751  0.32948  0.75790  1.17004  1.61668  2.18618 ********
   ERROR (M)...... -0.02297 -0.02048  0.0      0.01719  0.04067 -0.00493 ********
   C.G. VY (M/S)  =    204.     164.     124.      91.      60.      14.
   AT T=0.0.  C.G. VY= 222.     ; WHEN  VY=0.0.  T= 0.03888  AND  Y= 2.23278

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4   A=     0.0  B=  0.7710  ER=0.00293  EM= 0.0038  CD=  1.7278
   STATIONS 2-5   A=     0.0  B=  0.7162  ER=0.01154  EM=-0.0156  CD=  1.6049
   STATIONS 3-6   A=     0.0  B=  0.7599  ER=0.06759  EM=-0.0735  CD=  1.7029
   ALL STATIONS   A=     0.0  B=  0.9064  ER=0.07224  EM=-0.1267  CD=  2.0313

   STATIONS 1-4   A=  2261.0  B=  0.6435  ER=0.00408  EM=-0.0050
   STATIONS 2-5   A=  2261.0  B=  0.5315  ER=0.00389  EM=-0.0050
   STATIONS 3-6   A=  2261.0  B=  0.4081  ER=0.01843  EM=-0.0221
   ALL STATIONS   A=  2261.0  B=  0.5230  ER=0.02541  EM= 0.0464

   STATIONS 1-4   A=  1443.5  B=  0.6875  ER=0.00307  EM= 0.0049
   STATIONS 2-5   A=  3035.1  B=  0.4720  ER=0.00242  EM=-0.0028
   STATIONS 3-6   A=  2306.1  B=  0.4018  ER=0.01839  EM=-0.0218
   ALL STATIONS   A=  1997.8  B=  0.5680  ER=0.02417  EM= 0.0407
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                         SHOT   56 (10-05-77 ,NO. 5)

   DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
   SOLID FLAT NOSE PROJECTILE ; MASS=0.5425 KG  LENGTH=0.225 M

X-RAY STATION.......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00060  0.00249  0.00548  0.00941  0.01541  0.03205  *******

NOSE POSITION (M)..
   X-COMP.          0.17117  -.01628  0.16329  0.15754  0.13351  *******  *******
   Y-COMP.          0.10722  0.45081  0.85045  1.23662  1.64265  *******  *******

TAIL POSITION (M)..
   X-COMP.          *******  0.17602  0.00372  0.18638  0.16591  0.11321  *******
   Y-COMP.          *******  0.21473  0.63219  1.01012  1.42347  2.08311  *******

YAW ANGLE (DEG)....   -0.6     -1.6     -7.2    -11.1     -9.4     -4.2      0.0

C.G. POSITION (M)..
   X-COMP.          0.17353  0.07987  0.08351  0.17196  0.14971  0.09697  *******
   Y-COMP.          -.00526  0.33277  0.74132  1.12337  1.53306  2.19443  *******

COEF. OF CUBIC POLYNOMIAL:   -0.1064D 00    0.1880D 03    -0.6889D 04    0.1018D 06

FROM PONC. Y C.G. =-0.03320  0.31873  0.74132  1.14798  1.58229  2.18809 ********
   ERROR (M)...... -0.02795 -0.01404  0.0      0.02461  0.04923 -0.00635 ********
   C.G. VY (M/S)  =   210.     165.     122.      88.      59.      19.
   AT T=0.0.  C.G. VY= 230.      :  WHEN  VY=0.0.  T= 0.04435  AND  Y= 2.30201

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0   B=   0.7999  ER=0.00627  EM=-0.0100  CD=  1.7962
   STATIONS 2-5    A=      0.0   B=   0.8092  ER=0.00711  EM=-0.0084  CD=  1.8171
   STATIONS 3-6    A=      0.0   B=   0.7061  ER=0.06565  EM=-0.0708  CD=  1.5856
   ALL STATIONS    A=      0.0   B=   0.9019  ER=0.05738  EM=-0.1047  CD=  2.0253

   STATIONS 1-4    A=   2261.0   B=   0.6705  ER=0.00408  EM=-0.0066
   STATIONS 2-5    A=   2261.0   B=   0.6153  ER=0.00356  EM= 0.0055
   STATIONS 3-6    A=   2261.0   B=   0.2447  ER=0.15163  EM= 0.2385
   ALL STATIONS    A=   2261.0   B=   0.5000  ER=0.03649  EM= 0.0684

   STATIONS 1-4    A=   2614.4   B=   0.6514  ER=0.00357  EM=-0.0060
   STATIONS 2-5    A=   2035.4   B=   0.6405  ER=0.00282  EM=-0.0034
   STATIONS 3-6    A=   2203.0   B=   0.3614  ER=0.02940  EM=-0.0390
   ALL STATIONS    A=   1469.4   B=   0.6455  ER=0.02845  EM= 0.0492
```

```
                        SHOT   57 (11-05-77 .NO. 1)

     WET SAND  DENSITY= 2050 KG/M**3 ; APPROACH VELOCITY=125. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.5427 KG   LENGTH=0.225 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00068   0.00249   0.00552   0.00997   0.02502   0.05006   *******

NOSE POSITION (M)..
   X-COMP.          0.16078   -.02671   0.16951   0.18890   *******   *******   *******
   Y-COMP.          0.12017   0.43623   0.84735   1.28271   *******   *******   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.15673   -.03385   0.15883   *******   *******   *******
   Y-COMP.          *******   0.19447   0.62770   1.05746   *******   *******   *******

YAW ANGLE (DEG)....   1.2       0.8       2.0       5.6       0.0       0.0       0.0

C.G. POSITION (M)..
   X-COMP.          0.15627   0.06501   0.06783   0.17387   *******   *******   *******
   Y-COMP.          0.00776   0.31535   0.73753   1.17009   *******   *******   *******

COEF. OF CUBIC POLYNOMIAL:    -0.1201D 00     0.1920D 03    -0.7100D 04     0.8237D 05

FROM PONC. Y C.G. =-0.00046   0.31535   0.72909   1.15947   1.73070   0.26099 ********
   ERROR (M)....... -0.00822  0.0       -0.00844 -0.01062 ******** ******** ********
   C.G. VY (M/S)  =    193.      158.      118.       79.        4.    *****
   AT T=0.0. C.G. VY= 210.       ;  WHEN  VY=0.0.  T= 0.02611  AND  Y= 1.73309

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=      0.0  B=  0.7082  ER=0.00913  EM=-0.0119  CD=  1.1936

   ALL STATIONS   A=   4000.0  B=  0.5000  ER=0.00916  EM=-0.0106
```

SHOT 58 (11-05-77 ,NO. 2)

```
WET SAND  DENSITY= 2050 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.4969 KG  LENGTH=0.206 M

X-RAY STATION......    NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00050  0.00238  0.00498  0.00902  0.01500  0.02904  *******

NOSE POSITION (M)..
   X-COMP.          0.16512  -.02415  0.17312  -.00534  0.20712  *******  *******
   Y-COMP.          0.08341  0.44021  0.80490  1.22004  1.59940  *******  *******

TAIL POSITION (M)..
   X-COMP.          *******  0.16076  -.03057  0.15449  -.01529  0.21664  0.23343
   Y-COMP.          *******  0.22539  0.59916  0.99501  1.40695  1.92524  2.06264

YAW ANGLE (DEG)....    0.5      1.8      2.8      8.3      7.6      2.5      0.1

C.G. POSITION (M)..
   X-COMP.          0.16332  0.06831  0.07128  0.07458  0.09592  0.22562  0.23379
   Y-COMP.          -.01957  0.33280  0.70203  1.10753  1.50318  2.02785  2.16564

COEF. OF CUBIC POLYNOMIAL:  -0.1056D 00   0.1971D 03   -0.7890D 04   0.1252D 06

FROM PONC. Y C.G. =-0.05025  0.31670  0.70203  1.13109  1.55344  2.01981 ********
   ERROR (M)...... -0.03068 -0.01610  0.0      0.02357  0.05026 -0.00803 ********
   C.G. VY (M/S)  =    223.     171.     128.      89.      56.      15.
   AT T=0.0, C.G. VY= 242.     ;  WHEN  VY=0.0.  T= 0.03601  AND  Y= 2.07118

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4   A=      0.0  B=  0.8509  ER=0.00603  EM=-0.0099  CD=  1.3130
   STATIONS 2-5   A=      0.0  B=  0.8590  ER=0.01090  EM=-0.0142  CD=  1.3255
   STATIONS 3-6   A=      0.0  B=  0.8107  ER=0.06297  EM=-0.0695  CD=  1.2509
   ALL STATIONS   A=      0.0  B=  0.9896  ER=0.07049  EM=-0.1248  CD=  1.5270

   STATIONS 1-4   A=   3046.2  B=  0.6803  ER=0.00268  EM=-0.0044
   STATIONS 2-5   A=   2893.7  B=  0.6178  ER=0.00207  EM=-0.0034
   STATIONS 3-6   A=   2472.1  B=  0.4416  ER=0.02496  EM=-0.0312
   ALL STATIONS   A=   2088.3  B=  0.6670  ER=0.02949  EM= 0.0503
```

SHOT 59 (11-05-77 ,NO. 3)

WATER : APPROACH VELOCITY=181. M/S
SOLID FLAT NOSE PROJECTILE : MASS=0.5414 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00045	0.00233	0.00494	0.00897	0.01497	0.02904	*******
NOSE POSITION (M)..							
X-COMP.	*******	-.04057	0.15030	*******	*******	*******	*******
Y-COMP.	*******	0.45219	0.92710	*******	*******	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.12254	-.05669	*******	0.15682	*******	*******
Y-COMP.	*******	0.21254	0.68615	*******	1.39080	*******	*******
YAW ANGLE (DEG)....	0.0	2.5	3.5	0.0	1.8	0.0	0.0
C.G. POSITION (M)..							
X-COMP.	*******	0.04098	0.04670	*******	0.16369	*******	*******
Y-COMP.	*******	0.33257	0.80662	*******	1.50309	*******	*******

```
                    SHOT   60 ( 6-06-77 .NO. 1)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=177. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.3677 KG  LENGTH=0.152 M

X-RAY STATION......    NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00063  0.00209  0.00555  0.00904  0.02605  0.05019  *******

NOSE POSITION (M)..
   X-COMP.          0.17262  *******  *******  0.17997  0.14941  0.10560  *******
   Y-COMP.          0.11803  *******  *******  1.01096  1.65732  2.02908  *******

TAIL POSITION (M)..
   X-COMP.          *******  0.17409  0.18026  *******  0.17221  0.12948  0.10837
   Y-COMP.          *******  0.20828  0.59816  *******  1.50588  1.87782  2.11417

YAW ANGLE (DEG)....     1.2      0.8      0.9      0.0     -7.5     -5.4      5.7

C.G. POSITION (M)..
   X-COMP.          0.16957  0.17608  0.18251  0.17997  0.16081  0.11754  0.12326
   Y-COMP.          0.04209  0.28425  0.67413  0.93496  1.58160  1.95345  2.18870

COEF. OF CUBIC POLYNOMIAL:   -0.2213D-01    0.1441D 03    -0.4342D 04    0.4495D 05

FROM PONC. Y C.G. =-0.02751  0.24035  0.67413  0.96844  1.68023  1.93478 ********
   ERROR (M)...... -0.07000 -0.04390  0.0      0.03348  0.09863 -0.01867 ********
   C.G. VY (M/S)  =   211.     159.     100.      71.      24.    *****
   AT T=0.0.   C.G. VY= 245.      ;  WHEN   VY=0.0.   T= 0.04961   AND   Y= 1.93492

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=     0.0   B=   1.2765   ER=0.00513   EM=-0.0087   CD=   1.9429
   STATIONS 2-5    A=     0.0   B=   1.2286   ER=0.01966   EM=-0.0257   CD=   1.8700
   STATIONS 3-6    A=     0.0   B=   1.0331   ER=0.10855   EM=-0.1230   CD=   1.5724
   ALL STATIONS    A=     0.0   B=   1.3763   ER=0.11850   EM=-0.1912   CD=   2.0948

   STATIONS 1-4    A=  1992.7   B=   1.1040   ER=0.00371   EM=-0.0054
   STATIONS 2-5    A=  1330.0   B=   0.9271   ER=0.00470   EM=-0.0075
   STATIONS 3-6    A=   983.7   B=   0.5986   ER=0.06768   EM=-0.0825
   ALL STATIONS    A=   841.0   B=   1.0217   ER=0.06004   EM= 0.0986
```

SHOT 61 (6-06-77 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=123. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3668 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00059	0.00219	0.00551	0.01137	0.02201	0.05019	*******
NOSE POSITION (M)..							
X-COMP.	*******	0.15937	0.13506	*******	-.00212	*******	*******
Y-COMP.	*******	0.40342	0.78750	*******	1.48253	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.17831	0.18127	*******	0.01456	*******	0.01508
Y-COMP.	*******	0.24542	0.62695	*******	1.33994	*******	1.63452
YAW ANGLE (DEG)....	0.0	-7.9	-15.4	0.0	-4.8	0.0	2.1
C.G. POSITION (M)..							
X-COMP.	*******	0.16884	0.15817	*******	0.00622	*******	0.02051
Y-COMP.	*******	0.32442	0.70723	*******	1.41124	*******	1.71033

SHOT 62 (6-06-77 .NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=329. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3670 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00048	0.00183	0.00504	0.00933	0.01906	0.03011	*******
NOSE POSITION (M)..							
X-COMP.	*******	0.18273	0.22668	0.24062	0.21926	*******	0.16429
Y-COMP.	*******	0.45221	0.93174	1.27085	1.56568	*******	2.16910
TAIL POSITION (M)..							
X-COMP.	*******	0.15849	0.18614	*******	0.22697	*******	0.18210
Y-COMP.	*******	0.29647	0.78231	*******	1.42899	*******	2.02156
YAW ANGLE (DEG)....	0.0	8.9	8.0	-1.1	-3.8	0.0	-2.7
C.G. POSITION (M)..							
X-COMP.	*******	0.17061	0.20641	0.24340	0.22312	*******	0.17320
Y-COMP.	*******	0.37434	0.85703	1.19490	1.49734	*******	2.09533

COEF. OF CUBIC POLYNOMIAL: -0.2113D-01 0.2429D 03 -0.1542D 05 0.3598D 06

FROM FONC. Y C.G. =	0.03554	0.36538	0.85703	1.22246	1.49485	1.13103	********
ERROR (M)......	********	-0.00896	0.0	0.02756	-0.00248	********	********
C.G. VY (M/S) =	291.	206.	115.	61.	*****	*****	

AT T=0.0. C.G. VY= 339. ; WHEN VY=0.0. T= 0.01905 AND Y= 1.49485

FONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.7376 ER=0.09622 EM= 0.1280 CD= 2.6395

ALL STATIONS A= 5285.5 B= 0.9575 ER=0.01679 EM= 0.0276

SHOT 63 (7-06-77 .NO. 1)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=323. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3668 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00040	0.00149	0.00370	0.01030	0.01800	0.03000	*******
NOSE POSITION (M)..							
X-COMP.	*******	*******	0.18912	*******	*******	0.21618	*******
Y-COMP.	*******	*******	0.76629	*******	*******	2.06768	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	0.17683	*******	*******	0.23514	0.21603
Y-COMP.	*******	*******	0.61475	*******	*******	1.91335	2.13164
YAW ANGLE (DEG)....	0.0	0.0	3.1	0.0	0.0	-3.7	-4.8
C.G. POSITION (M)..							
X-COMP.	*******	*******	0.18298	*******	*******	0.22566	0.20349
Y-COMP.	*******	*******	0.69052	*******	*******	1.99052	2.20660

```
                         SHOT   64 ( 7-06-77 ,NO. 2)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=388. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.3668 KG  LENGTH=0.152 M

X-RAY STATION......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00029  0.00139  0.00348  0.00637  0.01093  0.02190  *******

NOSE POSITION (M)..
   X-COMP.          0.17536  0.18352  0.21483  0.25951  0.24874  *******  *******
   Y-COMP.          0.07978  0.40988  0.81679  1.17679  1.46885  *******  *******

TAIL POSITION (M)..
   X-COMP.          *******  0.15691  0.17551  0.22600  *******  *******  0.18482
   Y-COMP.          *******  0.25289  0.66697  1.02253  *******  *******  2.08466

YAW ANGLE (DEG)....   1.5      8.0     15.1     14.0      2.4      0.0     -5.3

C.G. POSITION (M)..
   X-COMP.          0.17138  0.17022  0.19517  0.24276  0.24238  *******  0.17084
   Y-COMP.          0.00388  0.33139  0.74188  1.09966  1.39312  *******  2.15936

COEF. OF CUBIC POLYNOMIAL:   -0.83490-01    0.32850 03    -0.29170 05    0.10500 07

FROM PONC. Y C.G. =-0.00143  0.31846  0.74188  1.10710  1.37567  0.88324 ********
   ERROR (M)...... -0.00531 -0.01292  0.0      0.00744 -0.01745 ******** ********
   C.G. VY (M/S)  =    333.     252.     164.      95.      27.     *****
   AT T=0.0.  C.G. VY= 361.       ;  WHEN  VY=0.0.  T= 0.01316  AND  Y= 1.40588

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=      0.0  B=  1.1412  ER=0.06498  EM= 0.1136  CD=  1.7326

   ALL STATIONS   A= 12041.2  B=  0.7227  ER=0.01178  EM=-0.0174
```

```
                         SHOT   65 ( 7-06-77 ,NO. 3)

     DRY SAND  DENSITY= 1538 KG/M**3 : APPROACH VELOCITY=**** M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.3668 KG  LENGTH=0.152 M

X-RAY STATION......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECCNDS)..... 0.00029  0.00138  0.)0348  0.00668  0.01250  0.02309  *******

NOSE POSITION (M)..
   X-COMP.          0.17315  0.18178  0.22201  0.25413  *******  *******  *******
   Y-CCMP.          0.09326  0.41919  0.82386  1.18371  *******  *******  *******

TAIL POSITICN (M)..
   X-CCMF.          *******  0.15616  0.17894  0.23518  *******  *******  0.19533
   Y-COMP.          *******  0.26437  0.67647  1.03326  *******  *******  2.07929

YAW ANGLE (DEG)....   1.5      10.0     17.1      8.0      0.0      0.0     -3.6

C.C. POSITICN (M)..
   X-COMP.          0.16930  0.16897  0.20048  0.24466  *******  *******  0.18594
   Y-CCMP.          0.31736  0.34178  0.75017  1.10849  *******  *******  2.15471

COEF. OF CUBIC POLYNCMIAL:    -0.8324D-01    0.3647D 03    -0.4490D 05    0.2545D 07

FRCM FONC. Y C.G. = 0.01425  0.3.4178  0.76347  1.13230  1.35230  0.45385 ********
   ERROR (M)...... -0.00311  0.0      0.01330  0.02381 ******** ******** ********
   C.G. VY (M/S)  =   351.     255.     157.      81.     *****    *****
   AT T=0.0.  C.G. VY= 387.      ;  WHEN  VY=0.0.  T= 0.01247  AND  Y= 1.35231

PONCELET CCEFFICIENTS BASED ON :

   ALL STATIONS   A=      0.0  B=  1.3220  ER=0.01539  EM=-0.0249  CD=  2.0072

   ALL STATIONS   A= 12368.0  B=  0.8334  ER=0.01585  EM= 0.0238
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```
                         SHOT   66 ( 7-06-77 ,NO. 4)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
      SOLID FLAT NOSE PROJECTILE : MASS=0.5424 KG  LENGTH=0.225 M

X-RAY STATION......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS).....  0.00033  0.00143  0.00351  0.00674  0.01251  0.02311  *******

NOSE POSITION (M)..
   X-COMP.           0.16626  0.16513  0.17418  0.18293  0.19343  *******  *******
   Y-COMP.           0.06524  0.33120  0.72380  1.17349  1.69099  *******  *******

TAIL POSITION (M)..
   X-COMP.           *******  *******  0.16703  0.17374  0.17706  0.19942  0.19074
   Y-COMP.           *******  *******  0.54102  0.93471  1.47413  2.04750  2.20380

YAW ANGLE (DEG)....    0.2      0.2      0.5      2.0      5.1      3.1      3.9

C.G. POSITION (M)..
   X-COMP.           0.16547  0.16454  0.17061  0.17834  0.18525  0.21157  0.20601
   Y-COMP.           -.04726  0.21870  0.63241  1.05410  1.58256  2.15934  2.31526

COEF. OF CUBIC POLYNOMIAL:   -0.1158D 00    0.2453D 03   -0.1169D 05    0.2310D 06

FROM PONC. Y C.G. =-0.08048  0.21342  0.63241  1.09028  1.61857  2.15141 *******
   ERROR (M)...... -0.03322 -0.00529  0.0      0.03618  0.03601 -0.00794 *******
   C.G. VY (M/S)  =   300.     239.     172.     118.      72.      34.
   AT T=0.C.   C.G. VY= 325.     ;  WHEN   VY=0.0.  T= 0.04180  AND  Y= 2.44554

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=     0.0  B=  0.8097  ER=0.01174  EM=-0.0147  CD=  1.8179
   STATIONS 2-5    A=     0.0  B=  0.8693  ER=0.00714  EM= 0.0095  CD=  1.9517
   STATIONS 3-6    A=     0.0  B=  0.5720  ER=0.09463  EM=-0.1010  CD=  1.2843
   ALL STATIONS    A=     0.0  B=  0.9001  ER=0.03717  EM=-0.0705  CD=  2.0208

   STATIONS 1-4    A=  2261.0  B=  0.7370  ER=0.01060  EM=-0.0134
   STATIONS 2-5    A=  2261.0  B=  0.7626  ER=0.01234  EM= 0.0196
   STATIONS 3-6    A=  2261.0  B=  0.3876  ER=0.07304  EM=-0.0840
   ALL STATIONS    A=  2261.0  B=  0.6817  ER=0.02948  EM= 0.0453

   STATIONS 1-4    A= 17211.3  B=  0.2783  ER=0.00387  EM=-0.0054
   STATIONS 2-5    A=     0.0  B=  0.8702  ER=0.00715  EM= 0.0092
   STATIONS 3-6    A=     0.0  B=  0.8702  ER=0.24041  EM=-0.2796
   ALL STATIONS    A=  1563.7  B=  0.7497  ER=0.02757  EM= 0.0362
```

SHOT 67 (8-06-77 ,NO. 1)

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DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5422 KG  LENGTH=0.225 M

X-RAY STATION......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00038  0.00189  0.00450  0.00748  0.01397  0.02484  *******

NOSE POSITION (M)..
   X-COMP.          0.16695  0.16426  0.16774  0.16747  *******  0.11345  *******
   Y-COMP.          0.06591  0.33849  0.70865  1.02299  *******  2.04023  *******

TAIL POSITION (M)..
   X-COMP.          *******  0.17238  *******  *******  0.17435  0.13632  0.10623
   Y-COMP.          *******  0.09720  *******  *******  1.28798  1.80707  2.16184

YAW ANGLE (DEG)....   -0.8     -0.9     -1.8     -2.6     -3.7     -4.5     -4.0

C.G. POSITION (M)..
   X-COMP.          0.16989  0.16832  0.17480  0.17767  0.16006  0.12489  0.09077
   Y-COMP.          -.04655  0.21785  0.59637  0.91095  1.39957  1.92365  2.27327

COEF. OF CUBIC POLYNOMIAL:   -0.1121D 00    0.1862D 03    -0.7400D 04    0.1290D 06

FROM PONC. Y C.G. =-0.06877  0.21307  0.59637  0.92896  1.43291  1.91690 ********
   ERROR (M)...... -0.02222 -0.00478  0.0      0.01801  0.03334 -0.00675 ********
   C.G. VY (M/S)  =   207.     169.     127.      98.      62.      31.
   AT T=0.C. C.G. VY= 220.     ;  WHEN  VY=0.0.  T= 0.04365  AND  Y= 2.18878

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=     0.0  B=  0.7569  ER=0.00704  EM=-0.0091  CD=  1.6984
   STATIONS 2-5    A=     0.0  B=  0.8390  ER=0.00321  EM=-0.0051  CD=  1.8831
   STATIONS 3-6    A=     0.0  B=  0.6539  ER=0.05196  EM=-0.0577  CD=  1.4676
   ALL STATIONS    A=     0.0  B=  0.8793  ER=0.03185  EM=-0.0614  CD=  1.9734

   STATIONS 1-4    A=  2261.0  B=  0.6353  ER=0.00569  EM=-0.0073
   STATIONS 2-5    A=  2261.0  B=  0.6675  ER=0.00575  EM= 0.0092
   STATIONS 3-6    A=  2261.0  B=  0.3835  ER=0.03138  EM=-0.0413
   ALL STATIONS    A=  2261.0  B=  0.5563  ER=0.02367  EM= 0.0446

   STATIONS 1-4    A=  6848.9  B=  0.3999  ER=0.00324  EM=-0.0041
   STATIONS 2-5    A=  1234.1  B=  0.7516  ER=0.00374  EM=-0.0048
   STATIONS 3-6    A=  2902.6  B=  0.3111  ER=0.02978  EM=-0.0393
   ALL STATIONS    A=  1444.7  B=  0.6751  ER=0.01999  EM= 0.0333
```

SHOT 68 (8-06-77 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5413 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00034	0.00183	0.00401	0.00708	0.01094	0.02149	*******
NOSE POSITION (M)..							
X-COMP.	0.17297	0.17245	0.17306	0.16383	0.12808	0.04804	*******
Y-COMP.	0.07933	0.43046	0.81785	1.21998	1.56430	2.12717	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.17373	0.18769	0.19691	0.18068	*******	0.05061
Y-COMP.	*******	0.20039	0.56924	0.98841	1.35727	*******	2.16468
YAW ANGLE (DEG)....	-1.4	-0.5	-4.1	-10.4	-12.7	-6.7	-5.4
C.G. POSITION (M)..							
X-COMP.	0.17827	0.17309	0.18038	0.18037	0.15438	0.07392	0.02972
Y-COMP.	-.03305	0.31543	0.70355	1.10420	1.46079	2.01769	2.27522

COEF. OF CUBIC POLYNOMIAL: -0.1065D 00 0.2461D 03 -0.1213D 05 0.2457D 06

FROM PONC. Y C.G. =	-0.05183	0.30092	0.70355	1.12223	1.49592	2.01272	********
ERROR (M)......	-0.01879	-0.01451	0.0	0.01803	0.03513	-0.00497	********
C.G. VY (M/S) =	265.	212.	161.	116.	80.	23.	

AT T=0.0. C.G. VY= 281. ; WHEN VY=0.0. T= 0.02743 AND Y= 2.08155

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.7796	ER=0.00375	EM=-0.0063	CD= 1.7467
STATIONS 2-5	A= 0.0	B= 0.7550	ER=0.00877	EM=-0.0111	CD= 1.6916
STATIONS 3-6	A= 0.0	B= 0.7560	ER=0.05968	EM=-0.0622	CD= 1.6940
ALL STATIONS	A= 0.0	B= 0.9103	ER=0.06311	EM=-0.1106	CD= 2.0396
STATIONS 1-4	A= 2261.0	B= 0.7073	ER=0.00285	EM=-0.0044	
STATIONS 2-5	A= 2261.0	B= 0.6478	ER=0.00506	EM=-0.0058	
STATIONS 3-6	A= 2261.0	B= 0.5627	ER=0.03515	EM=-0.0397	
ALL STATIONS	A= 2261.0	B= 0.7201	ER=0.03089	EM=-0.0554	
STATIONS 1-4	A= 4341.3	B= 0.6241	ER=0.00202	EM= 0.0031	
STATIONS 2-5	A= 4926.9	B= 0.5244	ER=0.00141	EM=-0.0024	
STATIONS 3-6	A= 4671.2	B= 0.3735	ER=0.01754	EM=-0.0230	
ALL STATIONS	A= 3850.8	B= 0.5710	ER=0.02073	EM= 0.0351	

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                          SHOT   69 ( 8-06-77 .NO. 3)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
      SOLID FLAT NOSE PROJECTILE : MASS=0.5425 KG   LENGTH=0.225 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS).....  0.00030   0.00181   0.00394   0.00690   0.01088   0.02137   *******

NOSE POSITION (M)..
    X-COMP.          0.17487   0.17195   0.17211   0.16285   0.12689   0.04551   *******
    Y-COMP.          0.08606   0.42572   0.80005   1.19311   1.54318   2.11837   *******

TAIL POSITION (M)..
    X-COMP.          *******   0.18129   0.19183   0.19922   0.17972   *******   0.05218
    Y-COMP.          *******   0.18595   0.57282   0.95804   1.33242   *******   2.17708

YAW ANGLE (DEG)....    -1.0      -1.7      -4.9     -10.3     -12.9      -7.4      -6.4

C.G. POSITION (M)..
    X-COMP.          0.17660   0.17662   0.18197   0.18104   0.15331   0.07425   0.02726
    Y-COMP.          -.02638   0.30584   0.68644   1.07558   1.43780   2.00960   2.28678

COEF. OF CUBIC POLYNOMIAL:   -0.9537D-01     0.2403D 03    -0.1177D 05     0.2400D 06

FROM FONC. Y C.G. =-0.04780  0.30002   0.68644   1.08869   1.47436   2.00449 ********
    ERROR (M)...... -0.02142 -0.00581  0.0       0.01311   0.03656  -0.00512 ********
    C.G. VY (M/S)  =    259.      207.      159.      116.       80.       26.
    AT T=0.0.  C.G. VY= 273.       :  WHEN  VY=0.0.  T= 0.02851  AND  Y= 2.09635

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4     A=     0.0  B=  0.7081  ER=0.00660  EM=-0.0100  CD=  1.5901
   STATIONS 2-5     A=     0.0  B=  0.7771  ER=0.01022  EM=-0.0134  CD=  1.7449
   STATIONS 3-6     A=     0.0  B=  0.7766  ER=0.04902  EM=-0.0540  CD=  1.7440
   ALL STATIONS     A=     0.0  B=  0.9013  ER=0.05557  EM=-0.1024  CD=  2.0239

   STATIONS 1-4     A=  2261.0  B=  0.6277  ER=0.00522  EM=-0.0079
   STATIONS 2-5     A=  2261.0  B=  0.6690  ER=0.00646  EM=-0.0080
   STATIONS 3-6     A=  2261.0  B=  0.5854  ER=0.02573  EM=-0.0321
   ALL STATIONS     A=  2261.0  B=  0.7032  ER=0.02661  EM=-0.0498

   STATIONS 1-4     A=  5067.9  B=  0.5358  ER=0.00378  EM=-0.0060
   STATIONS 2-5     A=  5067.9  B=  0.5358  ER=0.00210  EM=-0.0028
   STATIONS 3-6     A=  3305.7  B=  0.4626  ER=0.01695  EM=-0.0205
   ALL STATIONS     A=  3544.2  B=  0.5790  ER=0.02014  EM= 0.0366
```

SHOT 70 (8-06-77 ,NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=**** M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5429 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00029	0.00153	0.00362	0.00618	0.00939	0.01736	*******
NOSE POSITION (M)..							
X-COMP.	0.17782	0.18311	0.20601	0.24984	0.24033	*******	*******
Y-COMP.	0.10157	0.45067	0.88433	1.29023	1.63860	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.16487	0.16891	0.19870	0.26124	0.23449	*******
Y-COMP.	*******	0.22269	0.65957	1.06480	1.42671	1.98781	*******
YAW ANGLE (DEG)....	0.3	4.2	9.9	13.7	-4.8	1.1	0.0
C.G. POSITION (M)..							
X-COMP.	0.17664	0.17399	0.18746	0.22427	0.25079	0.23881	*******
Y-COMP.	-.01052	0.33668	0.77195	1.17752	1.53266	2.10023	*******

COEF. OF CUBIC POLYNOMIAL: -0.8634D-01 0.2931D 03 -0.1672D 05 0.4087D 06

FROM PONC. Y C.G. =	-0.02362	0.32076	0.77195	1.18752	1.56712	2.09497	********
ERROR (M)......	-0.01310	-0.01592	0.0	0.01001	0.03446	-0.00526	********
C.G. VY (M/S) =	305.	250.	188.	140.	100.	38.	

AT T=0.0. C.G. VY= 321. : WHEN VY=0.0. T= 0.02435 AND Y= 2.22633

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.7143	ER=0.00286	EM= 0.0043	CD= 1.6053
STATIONS 2-5	A= 0.0	B= 0.6591	ER=0.01414	EM=-0.0188	CD= 1.4811
STATIONS 3-6	A= 0.0	B= 0.7387	ER=0.03401	EM=-0.0396	CD= 1.6600
ALL STATIONS	A= 0.0	B= 0.8101	ER=0.05405	EM=-0.0926	CD= 1.8204
STATIONS 1-4	A= 2261.0	B= 0.6582	ER=0.00311	EM= 0.0051	
STATIONS 2-5	A= 2261.0	B= 0.5852	ER=0.01150	EM=-0.0152	
STATIONS 3-6	A= 2261.0	B= 0.6200	ER=0.01770	EM=-0.0242	
ALL STATIONS	A= 2261.0	B= 0.6863	ER=0.03344	EM=-0.0561	
STATIONS 1-4	A= 3178.6	B= 0.6454	ER=0.00380	EM= 0.0046	
STATIONS 2-5	A= 9476.4	B= 0.3620	ER=0.00380	EM=-0.0051	
STATIONS 3-6	A= 4119.3	B= 0.5258	ER=0.00905	EM=-0.0111	
ALL STATIONS	A= 5251.7	B= 0.5146	ER=0.01866	EM= 0.0345	

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                                SHOT   71 ( 8-06-77 ,NO. 5)

          DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=394. M/S
          SOLID FLAT NOSE PROJECTILE ; MASS=0.5423 KG   LENGTH=0.225 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS).....  0.00032   0.00158   0.00367   0.00624   0.00947   0.01742   *******

NOSE POSITION (M)..
    X-COMP.          0.17210   0.17048   0.17820   0.18083   0.18295   0.14725   *******
    Y-COMP.          0.09802   0.44252   0.87611   1.27120   1.61516   2.17784   *******

TAIL POSITION (M)..
    X-COMP.          *******   0.16887   0.17569   0.18278   0.18787   0.19103   *******
    Y-COMP.          *******   0.21762   0.64747   1.03131   1.38355   1.94496   *******

YAW ANGLE (DEG)....    -0.6       0.0       0.6       0.1      -0.1      -5.5       0.0

C.G. POSITION (M)..
    X-COMP.          0.17446   0.16968   0.17695   0.18181   0.18541   0.16914   *******
    Y-COMP.          -.01446   0.33007   0.76179   1.15126   1.49936   2.06140   *******

COEF. OF CUBIC POLYNOMIAL:    -0.9982D-01     0.2912D 03     -0.1699D 05     0.4247D 06

FROM PONC. Y C.G. =-0.02899   0.31594   0.76179   1.16675   1.53681   2.05538 ********
   ERROR (M)....... -0.01453 -0.01613   0.0       0.01549   0.03746  -0.00602 ********
   C.G. VY (M/S)  =    307.      247.      184.      135.       96.       40.
   AT T=0.0.  C.G. VY= 326.        ;  WHEN   VY=0.0.   T= 0.02553  AND   Y= 2.21111

PONCELET COEFFICIENTS BASED ON :

    STATIONS 1-4    A=     0.0  B=   0.7616  ER=0.00342  EM=-0.0056  CD=  1.7095
    STATIONS 2-5    A=     0.0  B=   0.7239  ER=0.01059  EM=-0.0132  CD=  1.6250
    STATIONS 3-6    A=     0.0  B=   0.7151  ER=0.03981  EM=-0.0454  CD=  1.6052
    ALL STATIONS    A=     0.0  B=   0.8332  ER=0.05029  EM=-0.0861  CD=  1.8704

    STATIONS 1-4    A=  2261.0  B=   0.7006  ER=0.00271  EM=-0.0037
    STATIONS 2-5    A=  2261.0  B=   0.6467  ER=0.00778  EM=-0.0094
    STATIONS 3-6    A=  2261.0  B=   0.5895  ER=0.02496  EM=-0.0304
    ALL STATIONS    A=  2261.0  B=   0.7042  ER=0.03038  EM=-0.0492

    STATIONS 1-4    A=  4042.4  B=   0.6565  ER=0.00243  EM= 0.0034
    STATIONS 2-5    A=  5670.1  B=   0.5339  ER=0.00352  EM=-0.0045
    STATIONS 3-6    A=  4733.7  B=   0.4597  ER=0.01526  EM=-0.0187
    ALL STATIONS    A=  4600.9  B=   0.5643  ER=0.02045  EM= 0.0375
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                         SHOT   72 ( 5-07-77 .NO. 1)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=403. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.3679 KG  LENGTH=0.152 M

X-RAY STATION......   NC.1     NC.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECCNDS)..... 0.00025  0.00126  0.00314  0.00596  0.01455  0.03186  *******

NOSE POSITION (M)..
   X-COMP.          0.17378  0.17497  0.18930  0.22473  0.24716  0.20304  *******
   Y-CCMP.          0.09454  0.39930  0.78511  1.16062  1.68218  2.05390  *******

TAIL POSITION (M)..
   X-CCMP.          *******  0.16501  0.16888  0.19365  0.24373  *******  0.18758
   Y-COMP.          *******  0.24432  0.63470  1.00660  1.52168  *******  2.17085

YAW ANGLE (DEG)....   0.5      3.8      7.8      9.0      0.1     -3.8     -3.7

C.G. POSITION (M)..
   X-CCMP.          0.17245  0.16999  0.17909  0.20919  0.24545  0.21309  0.17779
   Y-COMP.          0.01855  0.32181  0.70991  1.08361  1.60193  1.97857  2.24622

COEF. OF CUBIC POLYNOMIAL:   -0.18830-01    0.2658D 03    -0.1424D 05    0.2468D 06

FROM FONC. Y C.G. =-0.07825  0.27694  0.70991  1.11583  1.74376  1.95803 ********
   ERROR (M)....... -0.09680 -0.04487  0.0      0.03222  0.14183 -0.02054 ********
   C.G. VY (M/S)  =    427.     293.     184.     114.      41.     *****
   AT T=0.0.  C.G. VY= 481.      ;  WHEN  VY=0.0.  T= 0.02765  AND  Y= 1.98233

PONCELET COEFFICIENTS BASED ON :

   STATICNS 1-4   A=      0.0  B=  1.1583  ER=0.00747  EM=-0.0126  CD=  1.7639
   STATIONS 2-5   A=      0.0  B=  1.2617  ER=0.03922  EM=-0.0570  CD=  1.9214
   STATICNS 3-6   A=      0.0  B=  1.1984  ER=0.12399  EM=-0.1511  CD=  1.8250
   ALL STATIONS   A=      0.0  B=  1.3813  ER=0.17729  EM=-0.2636  CD=  2.1035

   STATICNS 1-4   A=  8932.1   B=  0.9080  ER=0.00459  EM= 0.0063
   STATIONS 2-5   A=  7181.1   B=  0.7577  ER=0.00471  EM=-0.0078
   STATIGNS 3-6   A=  2583.2   B=  0.7389  ER=0.07180  EM=-0.0926
   ALL STATIONS   A=  2720.9   B=  1.0306  ER=0.08119  EM= 0.1418
```

SHOT 73 (5-07-77 ,NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=405. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3666 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00030	0.00130	0.00318	0.00599	0.01458	0.03196	*******
NOSE POSITION (M)..							
X-COMP.	0.16585	0.16938	0.18389	0.21362	0.24374	0.22392	*******
Y-COMP.	0.08837	0.39164	0.77703	1.14695	1.62378	1.99810	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.16067	0.16695	0.18787	*******	0.23436	0.22262
Y-COMP.	*******	0.24077	0.62658	0.99587	*******	1.81897	2.10519
YAW ANGLE (DEG)....	1.4	1.8	5.7	6.2	2.8	-0.5	-1.8
C.G. POSITION (M)..							
X-COMP.	0.16227	0.16503	0.17542	0.20075	0.23632	0.22914	0.21785
Y-COMP.	0.01245	0.31621	0.70181	1.07141	1.55314	1.90854	2.18104

COEF. OF CUBIC POLYNOMIAL: -0.3709D-01 0.2685D 03 -0.1471D 05 0.2569D 06

FROM PONC. Y C.G. =	-0.09030	0.26649	0.70181	1.10331	1.71336	1.88589	********
ERROR (M)......	-0.10275	-0.04971	0.0	0.03190	0.16021	-0.02265	********
C.G. VY (M/S) =	438.	257.	183.	113.	39.	*****	

AT T=0.0. C.G. VY= 512. ; WHEN VY=0.0. T= 0.02674 AND Y= 1.92502

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 1.2132	ER=0.00778	EM=-0.0127	CD= 1.3409
STATIONS 2-5	A= 0.0	B= 1.3293	ER=0.04518	EM=-0.0661	CD= 2.0171
STATIONS 3-6	A= 0.0	B= 1.2871	ER=0.12310	EM=-0.1545	CD= 1.9531
ALL STATIONS	A= 0.0	B= 1.4213	ER=0.19567	EM= 0.2969	CD= 2.1567

STATIONS 1-4	A= 7593.3	B= 0.9982	ER=0.00569	EM= 0.0080
STATIONS 2-5	A= 8054.8	B= 0.7395	ER=0.00454	EM=-0.0075
STATIONS 3-6	A= 2451.7	B= 0.8158	ER=0.07348	EM=-0.0961
ALL STATIONS	A= 2839.1	B= 1.0647	ER=0.08970	EM= 0.1602

SHOT 74 (5-07-77 ,NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=334. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5411 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00032	0.00138	0.00327	0.00545	0.00839	0.01497	*******
NOSE POSITION (M)..							
X-COMP.	0.17405	0.17305	0.19517	0.22924	0.25824	0.24681	*******
Y-COMP.	0.09581	0.38526	0.78998	1.15427	1.51064	1.97940	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.16275	0.16424	0.18515	*******	0.25139	*******
Y-COMP.	*******	0.12971	0.61526	0.95275	*******	1.74118	*******
YAW ANGLE (DEG)....	1.0	3.2	10.2	10.4	5.4	0.5	0.0
C.G. POSITION (M)..							
X-COMP.	0.17012	0.17040	0.17971	0.20720	0.23716	0.24910	*******
Y-COMP.	-.01662	0.25749	0.70262	1.05351	1.40013	1.86029	*******

COEF. OF CUBIC POLYNOMIAL: -0.1157D 00 0.3028D 03 -0.1860D 05 0.4802D 06

FROM FONC. Y C.G. =	-0.03712	0.27200	0.70262	1.07269	1.42500	1.85509	********
ERROR (M)......	-0.02050	0.01452	0.0	0.01918	0.02886	-0.00520	********
C.G. VY (M/S) =	322.	265.	197.	146.	100.	35.	

AT T=0.0, C.G. VY= 344. ; WHEN VY=0.0, T= 0.01947 AND Y= 1.97183

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.6006	ER=0.01844	EM=-0.0227	CD= 1.3452
STATIONS 2-5	A= 0.0	B= 0.8768	ER=0.00543	EM=-0.0087	CD= 1.9638
STATIONS 3-6	A= 0.0	B= 0.6709	ER=0.08252	EM=-0.0841	CD= 1.5026
ALL STATIONS	A= 0.0	B= 0.9140	ER=0.06055	EM=-0.1061	CD= 2.0472
STATIONS 1-4	A= 2261.0	B= 0.5516	ER=0.01784	EM=-0.0221	
STATIONS 2-5	A= 2261.0	B= 0.8166	ER=0.00389	EM=-0.0067	
STATIONS 3-6	A= 2261.0	B= 0.5625	ER=0.07238	EM=-0.0741	
ALL STATIONS	A= 2261.0	B= 0.8121	ER=0.04339	EM=-0.0798	
STATIONS 1-4	A= 28485.4	B= 0.0018	ER=0.01131	EM=-0.0152	
STATIONS 2-5	A= 4248.4	B= 0.7626	ER=0.00364	EM=-0.0049	
STATIONS 3-6	A= 13360.0	B= 0.0909	ER=0.03617	EM=-0.0531	
ALL STATIONS	A= 7456.6	B= 0.5468	ER=0.01928	EM= 0.0289	

SHOT 75 (5-07-77 ,NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=349. M/S
SOLID STEP TIER PROJECTILE ; MASS=0.5155 KG LENGTH=0.219 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00035	0.00142	0.00332	0.00550	0.00842	0.01503	*******
NOSE POSITION (M)..							
X-COMP.	0.17236	0.17565	0.19265	0.22720	0.25672	0.23890	*******
Y-COMP.	0.10584	0.40596	0.81826	1.19233	1.52233	2.04605	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.16012	0.15891	0.18208	0.22859	0.24113	*******
Y-COMP.	*******	0.18901	0.60617	0.96053	1.33694	1.82182	*******
YAW ANGLE (DEG)....	1.2	4.4	9.6	10.7	8.5	0.4	0.0
C.G. POSITION (M)..							
X-COMP.	0.16770	0.16772	0.17542	0.20415	0.24235	0.24004	*******
Y-COMP.	-.00593	0.29514	0.70993	1.07393	1.42763	1.93151	*******

COEF. OF CUBIC POLYNOMIAL: -0.1031D 00 0.2997D 03 -0.1800D 05 0.4705D 06

FROM PONC. Y C.G. =	-0.02360	0.28227	0.70993	1.08218	1.44744	1.92890	********
ERROR (M)......	-0.01767	-0.01287	0.0	0.00826	0.01980	-0.00261	********
C.G. VY (M/S) =	314.	260.	196.	148.	105.	46.	

AT Y=0.C. C.G. VY= 336. ; WHEN VY=0.0. T= 0.02218 AND Y= 2.08701

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.6962	ER=0.00343	EM= 0.0049	CD= 1.4854
STATIONS 2-5	A= 0.0	B= 0.6875	ER=0.00953	EM=-0.0123	CD= 1.4670
STATIONS 3-6	A= 0.0	B= 0.7194	ER=0.04192	EM=-0.0443	CD= 1.5350
ALL STATIONS	A= 0.0	B= 0.8382	ER=0.04669	EM=-0.0810	CD= 1.7886

STATIONS 1-4	A= 5164.4	B= 0.5979	ER=0.00167	EM= 0.0026
STATIONS 2-5	A= 6312.4	B= 0.5066	ER=0.00367	EM=-0.0047
STATIONS 3-6	A= 7224.8	B= 0.3988	ER=0.01061	EM=-0.0129
ALL STATIONS	A= 6006.4	B= 0.5436	ER=0.01375	EM= 0.0198

SHOT 76 (5-07-77 .NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=405. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3669 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00030	0.00116	0.00301	0.00580	0.01131	0.02714	*******
NOSE POSITION (M)..							
X-COMP.	0.14245	0.15009	0.18199	0.24544	*******	0.19985	*******
Y-COMP.	0.09824	0.38482	0.80532	1.20596	*******	2.12230	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.13110	0.14157	0.19182	*******	0.22945	0.20610
Y-COMP.	*******	0.22635	0.65645	1.04486	*******	1.98639	2.21971
YAW ANGLE (DEG)....	1.5	6.7	15.2	19.9	0.0	-4.4	-6.9
C.G. POSITION (M)..							
X-COMP.	0.13860	0.14060	0.16178	0.21863	*******	0.21465	0.18797
Y-COMP.	0.02234	0.30559	0.73089	1.12541	*******	2.05435	2.29352

COEF. OF CUBIC POLYNOMIAL: -0.7224D-01 0.3485D 03 -0.2849D 05 0.6829D 06

FROM FONC. Y C.G. =	0.01574	0.29239	0.73089	1.16972	1.67999	2.05394	*******
ERROR (M)......	-0.00659	-0.01320	0.0	0.04431	********	-0.00041	********
C.G. VY (M/S) =	363.	288.	195.	128.	66.	*****	

AT T=0.0. C.G. VY= 400. ; WHEN VY=0.0. T= 0.02449 AND Y= 2.06812

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.2956 ER=0.13839 EM= 0.1906 CD= 1.9676

ALL STATIONS A= 4022.5 B= 0.8077 ER=0.02335 EM= 0.0443

SHOT 77 (6-07-77 ,NO. 1)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=443. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3665 KG LENGTH=0.152 M

X-RAY STATION......	NC.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECCNDS).....	0.00026	0.00112	0.00298	0.00603	0.01129	0.02718	*******
NOSE POSITICN (M)..							
X-CCMP.	0.13737	0.13800	0.15501	0.16545	*******	0.12676	*******
Y-CCMP.	0.09415	0.37856	0.80019	1.22591	*******	2.12802	*******
TAIL POSITICN (M)..							
X-COMP.	*******	0.31629	0.14224	0.16625	*******	0.15250	*******
Y-COMP.	*******	0.63730	0.64742	1.06393	*******	1.96940	*******
YAW ANGLE (DEG)....	1.2	4.6	5.6	-0.8	0.0	-4.4	0.0
C.G. POSITICN (M)..							
X-CCMP.	0.13419	0.22715	0.14863	0.16585	*******	0.13963	*******
Y-COMP.	0.01822	0.50813	0.72381	1.14492	*******	2.04871	*******

COEF. OF CUBIC POLYNOMIAL: 0.5494D-02 0.3615D 03 -0.3433D 05 0.8755D 06

FRCM FCNC. Y C.G. =	0.07564	0.32441	0.72381	1.16581	1.62360	2.04876	********
ERROR (M)......	0.05743	-0.18372	0.0	0.02089	********	0.00005	********
C.G. VY (M/S) =	322.	259.	181.	116.	65.	*****	

AT T=0.0. C.G. VY= 346. ; WHEN VY=0.0. T= 0.02630 AND Y= 2.05007

PCNCELET CCEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.3323 ER=0.13543 EM=-0.2274 CC= 2.0212

ALL STATICNS A= 3359.7 B= 0.8307 ER=0.09681 EM=-0.1837

SHOT 78 (6-07-77 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=342. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3673 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00029	0.00113	0.00278	0.00526	0.01075	0.02245	*******
NOSE POSITION (M)..							
X-COMP.	0.14118	*******	0.14668	0.14022	0.11212	*******	*******
Y-COMP.	0.09512	*******	0.72010	1.07128	1.53473	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.13967	0.15180	0.15183	0.14413	0.08556	*******
Y-COMP.	*******	0.20518	0.56388	0.91492	1.39244	1.92601	*******
YAW ANGLE (DEG)....	-0.0	-0.6	-1.0	-2.2	-11.0	-6.8	0.0
C.G. POSITION (M)..							
X-COMP.	0.14131	0.13808	0.14924	0.14603	0.12813	0.06782	*******
Y-COMP.	0.01912	0.28116	0.64199	0.99310	1.46359	1.99991	*******

COEF. OF CUBIC POLYNOMIAL: -0.3835D-01 0.2835D 03 -0.1789D 05 0.4144D 06

FROM PONC. Y C.G. =	-0.02825	0.25306	0.64199	1.02924	1.53149	1.98894	********
ERROR (M)......	-0.04737	-0.02810	0.0	0.03614	0.06790	-0.01097	********
C.G. VY (M/S) =	387.	290.	194.	127.	66.	19.	

AT T=0.C. C.G. VY= 437. ; WHEN VY=0.0. T= 0.03025 AND Y= 2.06164

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 1.2154	ER=0.00569	EM=-0.0097	CD= 1.8478
STATIONS 2-5	A= 0.0	B= 1.1194	ER=0.00990	EM=-0.0128	CD= 1.7018
STATIONS 3-6	A= 0.0	B= 0.8682	ER=0.08470	EM=-0.0974	CD= 1.3230
ALL STATIONS	A= 0.0	B= 1.2334	ER=0.06251	EM=-0.1100	CD= 1.8752

STATIONS 1-4	A= 5919.8	B= 1.0677	ER=0.00394	EM=-0.0063
STATIONS 2-5	A= 3558.0	B= 0.9573	ER=0.00478	EM=-0.0078
STATIONS 3-6	A= 4403.6	B= 0.4698	ER=0.05162	EM=-0.0647
ALL STATIONS	A= 2331.7	B= 0.9995	ER=0.04259	EM= 0.0679

SHOT 79 (6-07-77 .NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=396. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3667 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00030	0.00116	0.00279	0.00507	0.01076	0.02250	*******
NOSE POSITION (M)..							
X-COMP.	0.14174	*******	*******	0.18412	0.22230	0.22446	*******
Y-COMP.	0.05886	*******	*******	1.10432	1.61506	2.08618	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.13509	0.14418	0.16449	0.20183	0.23959	0.24530
Y-COMP.	*******	0.21826	0.59510	0.95275	1.47356	1.93359	2.15778
YAW ANGLE (DEG)....	1.1	1.3	3.2	4.5	8.4	-2.6	-6.0
C.G. POSITION (M)..							
X-COMP.	0.13896	0.13854	0.15252	0.17431	0.21207	0.23203	0.22950
Y-COMP.	0.02291	0.29418	0.67064	1.02854	1.54431	2.00989	2.23212

COEF. OF CUBIC POLYNOMIAL: -0.4748D-01 0.3002D 03 -0.1870D 05 0.4185D 06

FROM FONC. Y C.G. =	-0.02728	0.26583	0.67064	1.05436	1.61000	2.00016	********
ERROR (M)......	-0.05019	-0.02835	0.0	0.02583	0.06569	-0.00973	********
C.G. VY (M/S) =	391.	300.	206.	139.	67.	6.	

AT T=0.0. C.G. VY= 437. ; WHEN VY=0.0. T= 0.02402 AND Y= 2.00480

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 1.0356	ER=0.00410	EM=-0.0070	CD= 1.5718
STATIONS 2-5	A= 0.0	B= 1.0201	ER=0.01697	EM=-0.0232	CD= 1.5484
STATIONS 3-6	A= 0.0	B= 0.9567	ER=0.09769	EM=-0.1056	CD= 1.4522
ALL STATIONS	A= 0.0	B= 1.2274	ER=0.09309	EM=-0.1604	CD= 1.8630

STATIONS 1-4	A= 6154.9	B= 0.9025	ER=0.00289	EM=-0.0041
STATIONS 2-5	A= 7118.1	B= 0.7350	ER=0.00324	EM=-0.0053
STATIONS 3-6	A= 5236.4	B= 0.5090	ER=0.04451	EM=-0.0516
ALL STATIONS	A= 3999.5	B= 0.8699	ER=0.04099	EM= 0.0657

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                         SHOT   80 ( 6-07-77 ,NO. 4)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=375. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.5421 KG   LENGTH=0.225 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00029   0.00095   0.00271   0.00436   0.00699   0.01005   *******

NOSE POSITION (M)..
   X-COMP.          0.13916   0.13586   *******   0.14653   0.13480   0.11921   *******
   Y-COMP.          0.08230   0.29734   *******   1.06828   1.43824   1.73892   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.13362   *******   0.15721   0.15253   0.14369   0.11525
   Y-COMP.          *******   0.06184   *******   0.84305   1.18956   1.47577   2.21561

YAW ANGLE (DEG)....   0.6       0.1      -0.5      -1.4      -2.0      -3.3      -6.1

C.G. POSITION (M)..
   X-COMP.          0.13680   0.13474   *******   0.15187   0.14367   0.13145   0.09146
   Y-COMP.          -.03018   0.17959   *******   0.95816   1.31410   1.60735   2.32557

COEF. OF CUBIC POLYNOMIAL:   -0.1302D 00    0.3506D 03    -0.2732D 05    0.9600D 06

FROM POLY. Y C.G. =-0.03706   0.18341   0.64206   0.95816   1.32400   1.61443 ********
   ERROR (M)....... -0.00688   0.00382 ********   0.0       0.00990   0.00708 ********
   C.G. VY (M/S)  =    367.      312.      219.      167.      115.       77.
   AT T=0.0,  C.G. VY= 398.      ;  WHEN  VY=0.0,  T= 0.02046  AND  Y= 1.98277

FORCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=     0.0   B=   0.8392  ER=0.02744  EM= 0.0488  CD=  1.3830

   ALL STATIONS    A=  2261.0   B=   0.7810  ER=0.01999  EM= 0.0345

   ALL STATIONS    A=  6248.3   B=   0.6813  ER=0.00725  EM= 0.0099
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SHOT 81 (7-07-77 ,NO. 1)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=379. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.5422 KG LENGTH=0.225 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00028	0.00092	0.00279	0.00466	0.00758	0.01121	*******
NOSE POSITION (M)..							
X-COMP.	0.14829	0.14437	0.16110	*******	*******	0.22848	*******
Y-COMP.	0.08235	0.29078	0.75643	*******	*******	1.92556	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	0.14679	*******	0.16419	*******	*******
Y-COMP.	*******	*******	0.52374	*******	1.27110	*******	*******
YAW ANGLE (DEG)....	0.2	0.5	3.7	3.0	3.6	4.3	0.0
C.G. POSITION (M)..							
X-COMP.	0.14750	0.14260	0.15395	*******	0.17829	0.21185	*******
Y-COMP.	-.03015	0.17829	0.64009	*******	1.38271	1.81430	*******

COEF. OF CUBIC POLYNOMIAL: -0.1177D 00 0.3371D 03 -0.2603D 05 0.1011D 07

FROM FUNC. Y C.G. =	-0.03670	0.16719	0.64009	0.99504	1.41519	1.80466	********
ERROR (M)......	-0.00655	-0.01111	0.0	********	0.03248	-0.00963	********
C.G. VY (M/S) =	342.	298.	215.	168.	124.	93.	

AT T=0.C. C.G. VY= 365. ; WHEN VY=0.0, T= 0.05700 AND Y= 3.23855

FONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.7036 ER=0.01845 EM= 0.0319 CD= 1.5790

ALL STATIONS A= 2261.0 B= 0.6236 ER=0.01863 EM= 0.0335

ALL STATIONS A= 988.9 B= 0.6689 ER=0.01813 EM= 0.0325

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                         SHOT   82 ( 7-07-77 .NO. 2)

     DRY SAND   DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=379. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.5420 KG   LENGTH=0.225 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00037   0.00132   0.00281   0.00502   0.00753   0.01306   *******

NOSE POSITION (M)..
   X-COMP.          0.14967   0.15333   0.17443   0.20096   0.25149   0.25083   *******
   Y-COMP.          0.10457   0.39542   0.75334   1.16115   1.53634   2.00474   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.13711   0.13391   0.15554   0.19530   *******   *******
   Y-COMP.          *******   0.15690   0.51766   0.92919   1.35057   *******   *******

YAW ANGLE (DEG)....   1.1       3.8      10.6      13.4      17.1       0.4       0.0

C.G. POSITION (M)..
   X-COMP.          0.14555   0.14522   0.15417   0.17825   0.22340   0.24326   *******
   Y-COMP.          -.00785   0.27616   0.63550   1.04517   1.44346   1.89225   *******

COEF. OF CUBIC POLYNOMIAL:    -0.1182D 00     0.3184D 03    -0.1965D 05     0.5411D 06

FROM FCNC. Y C.G. =-0.02572   0.26339   0.63550   1.05319   1.45180   1.88854 ********
   ERROR (M)...... -0.01787 -0.01277   0.0       0.00802   0.00834 -0.00371 ********
   C.G. VY (M/S)  =   335.      281.      221.      163.      114.       60.
   AT T=0.0.   C.G. VY= 361.      ;   WHEN   VY=0.0.   T= 0.02149   AND   Y= 2.13064

FORCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0   B=   0.6758  ER=0.00259  EM= 0.0034  CD=  1.5162
   STATIONS 2-5    A=      0.0   B=   0.6515  ER=0.00637  EM=-0.0086  CD=  1.4617
   STATIONS 3-6    A=      0.0   B=   0.6414  ER=0.04236  EM=-0.0439  CD=  1.4390
   ALL STATIONS    A=      0.0   B=   0.7985  ER=0.03310  EM=-0.0606  CD=  1.7914

   STATIONS 1-4    A=   2261.0   B=   0.6487  ER=0.00154  EM= 0.0024
   STATIONS 2-5    A=   2261.0   B=   0.5952  ER=0.00463  EM=-0.0061
   STATIONS 3-6    A=   2261.0   B=   0.5594  ER=0.03460  EM=-0.0367
   ALL STATIONS    A=   2261.0   B=   0.7072  ER=0.02389  EM=-0.0440

   STATIONS 1-4    A=   4476.5   B=   0.6092  ER=0.00200  EM= 0.0026
   STATIONS 2-5    A=   5540.2   B=   0.5152  ER=0.00213  EM=-0.0026
   STATIONS 3-6    A=  10667.0   B=   0.2721  ER=0.01090  EM=-0.0147
   ALL STATIONS    A=   6525.5   B=   0.5401  ER=0.01123  EM=-0.0179
```

SHOT 83 (7-07-77 ,NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=458. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3673 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00035	0.00120	0.00310	0.00594	0.01127	0.02102	*******
NOSE POSITION (M)..							
X-COMP.	0.14901	0.15584	0.20296	0.24506	0.23529	0.19840	*******
Y-COMP.	0.13040	0.41368	0.82208	1.18742	1.52303	1.85792	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.12570	0.15414	0.23682	*******	*******	0.15255
Y-COMP.	*******	0.26031	0.67751	1.02982	*******	*******	2.13152
YAW ANGLE (DEG)....	2.5	10.6	18.9	8.7	2.9	-4.2	-4.4
C.G. POSITION (M)..							
X-COMP.	0.14252	0.14077	0.17855	0.24094	0.22774	0.20937	0.14092
Y-COMP.	0.05468	0.33700	0.74980	1.10862	1.44741	1.78272	2.20663

COEF. OF CUBIC POLYNOMIAL: -0.2231D-01 0.3031D 03 -0.2125D 05 0.5191D 06

FROM PONC. Y C.G. =	-0.00227	0.29854	0.74980	1.15846	1.56771	1.76004	********
ERROR (M)......	-0.05695	-0.03846	0.0	0.04984	0.12031	-0.02267	********
C.G. VY (M/S) =	418.	305.	186.	111.	50.	*****	

AT T=0.0. C.G. VY= 492. ; WHEN VY=0.0. T= 0.01966 AND Y= 1.76496

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 1.3687	ER=0.01056	EM=-0.0178	CD= 2.0809
STATIONS 2-5	A= 0.0	B= 1.3377	ER=0.03005	EM=-0.0369	CD= 2.0338
STATIONS 3-6	A= 0.0	B= 1.1298	ER=0.10209	EM=-0.1229	CD= 1.7177
ALL STATIONS	A= 0.0	B= 1.3824	ER=0.14623	EM= 0.2157	CD= 2.1018

STATIONS 1-4	A= 11997.6	B= 1.0491	ER=0.00635	EM= 0.0078
STATIONS 2-5	A= 9062.3	B= 0.8793	ER=0.00652	EM=-0.0105
STATIONS 3-6	A= 5227.2	B= 0.6047	ER=0.06154	EM=-0.0759
ALL STATIONS	A= 5253.0	B= 0.9996	ER=0.06662	EM= 0.1203

SHOT 84 (7-07-77 .NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=455. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3670 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECCNDS).....	0.00034	0.00119	0.00310	0.00595	0.01125	0.02407	*******
NOSE POSITICN (M)..							
X-COMP.	0.14452	0.15088	0.19493	0.24386	0.23756	*******	0.14981
Y-CCMP.	0.12246	0.40723	0.82774	1.18546	1.45304	*******	2.19491
TAIL PCSITION (M)..							
X-CCMP.	*******	0.13149	0.14607	0.22019	*******	*******	0.17856
Y-COMP.	*******	0.25239	0.68804	1.03793	*******	*******	2.05282
YAW ANGLE (DEG)....	0.9	6.5	19.2	13.5	1.0	0.0	-5.7
C.G. POSITION (M)..							
X-CCMP.	0.14213	0.14119	0.17050	0.23203	0.23504	*******	0.16419
Y-COMP.	0.04650	0.32981	0.75789	1.11170	1.37708	*******	2.12387

COEF. OF CUBIC PCLYNCMIAL: -0.7192D-01 0.3728D 03 -0.3776D 05 0.1429D 07

FRCM FCNC. Y C.G. =	0.04450	0.32317	0.75789	1.13692	1.37316	-1.01518	********
ERROR (M).......	-0.00200	-0.00664	0.0	0.02522	-0.00392	********	********
C.G. VY (M/S) =	373.	288.	180.	95.	0.	*****	

AT T=0.0. C.G. VY= 420. ; WHEN VY=0.0. T= 0.01127 AND Y= 1.37316

FONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.3215 ER=0.11153 EM= 0.1961 CD= 2.0075

ALL STATIONS A= 15700.6 B= 0.7768 ER=0.01323 EM= 0.0252

```
                      SHOT  85 ( 7-07-77 .NO. 5)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=448. M/S
      SOLID FLAT NOSE PROJECTILE ; MASS=0.3669 KG   LENGTH=0.152 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00036   0.00121   0.00313   0.00598   0.01259   0.02606   *******

NOSE POSITION (M)..
   X-COMP.          0.14676   0.14454   0.15537   0.15845   0.15995   0.12929   *******
   Y-COMP.          0.11676   0.39945   0.82888   1.21537   1.69073   2.03751   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.13826   0.14699   0.15984   0.17234   0.12777   0.11738
   Y-COMP.          *******   0.24868   0.67987   1.06653   1.53333   2.26432   2.12169

YAW ANGLE (DEG)....   0.6       2.5       3.2       2.3      -2.4      -4.7      -1.5

C.G. POSITION (M)..
   X-COMP.          0.14517   0.14140   0.15118   0.15915   0.16615   0.12853   0.11353
   Y-COMP.          0.04078   0.32407   0.75438   1.14095   1.61203   2.15092   2.19759

COEF. OF CUBIC POLYNOMIAL:    -0.32730-01     0.2948D 03    -0.1784D 05     0.3741D 06

FROM PONC. Y C.G. =-0.03746   0.27898   0.75438   1.18559   1.75196   2.12622 ********
   ERROR (M)...... -0.07824 -0.04508   0.0       0.04464   0.13993 -0.02470 ********
   C.G. VY (M/S)   =   442.      320.      194.      120.       54.        9.
   AT T=0.0.  C.G. VY= 528.      :  WHEN  VY=0.0.  T= 0.02968  AND  Y= 2.14236

FONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0  B=   1.2188  ER=0.00798  EM=-0.0136  CD=  1.6510
   STATIONS 2-5    A=      0.0  B=   1.1931  ER=0.03122  EM=-0.0410  CD=  1.8120
   STATIONS 3-6    A=      0.0  B=   0.9369  ER=0.09492  EM=-0.1242  CD=  1.4229
   ALL STATIONS    A=      0.0  B=   1.2467  ER=0.11334  EM=-0.1761  CD=  1.8934

   STATIONS 1-4    A=   8783.4  B=   1.0008  ER=0.00570  EM=-0.0070
   STATIONS 2-5    A=   7217.3  B=   0.8140  ER=0.00653  EM=-0.0106
   STATIONS 3-6    A=   2555.6  B=   0.6597  ER=0.07478  EM=-0.0856
   ALL STATIONS    A=   2456.7  B=   1.0092  ER=0.07789  EM= 0.1399
```

SHOT 86 (7-07-77 .NO. 6)

WATER ; APPROACH VELOCITY=446. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3676 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00031	0.00087	0.00262	0.00463	0.00655	0.01192	*******
NOSE POSITION (M)..							
X-COMP.	0.15803	0.14673	*******	*******	*******	*******	*******
Y-COMP.	0.03577	0.29146	*******	*******	*******	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.13584	0.13633	*******	*******	*******	*******
Y-COMP.	*******	0.12388	0.78005	*******	*******	*******	*******
YAW ANGLE (DEG)....	2.5	1.8	3.8	0.0	0.0	0.0	0.0
C.G. POSITION (M)..							
X-COMP.	0.15141	0.14129	0.14638	*******	*******	*******	*******
Y-COMP.	-.03994	0.20767	0.85538	*******	*******	*******	*******

SHOT 87 (8-07-77 .NO. 1)

```
DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=446. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3670 KG  LENGTH=0.152 M

X-RAY STATION......     NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00031   0.00117   0.00308   0.00584   0.01295   0.02599   *******

NOSE POSITION (M)..
   X-COMP.          0.18584   0.19218   0.22781   0.24599   0.21280   0.15606   *******
   Y-COMP.          0.12087   0.40499   0.82494   1.18941   1.62011   2.03826   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.18125   0.19162   0.26357   0.24273   0.17969   *******
   Y-COMP.          *******   0.24881   0.67905   1.03385   1.47497   1.80995   *******

YAW ANGLE (DEG)....   -0.2      5.4      16.1      -1.5     -10.5      -9.3       0.0

C.G. POSITION (M)..
   X-COMP.          0.18624   0.18672   0.20972   0.25478   0.22777   0.16788   *******
   Y-COMP.          0.04487   0.32690   0.75200   1.11163   1.54754   1.92411   *******

COEF. OF CUBIC POLYNOMIAL:   -0.1399D-01    0.2905D 03    -0.1798D 05    0.3721D 06

FROM PONC. Y C.G. =-0.03582  0.28659   0.75200   1.16105   1.69097   1.90058 ********
   ERROR (M)...... -0.08070 -0.04031   0.0       0.04942   0.14343  -0.02352 ********
   C.G. VY (M/S)  =   447.      317.      190.      116.       46.     *****
   AT T=0.0.  C.G. VY= 523.       ;  WHEN  VY=0.0.  T= 0.02344  AND  Y= 1.91280

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4   A=      0.0   B=  1.2598  ER=0.01081  EM=-0.0171  CD=  1.9139
   STATIONS 2-5   A=      0.0   B=  1.3307  ER=0.03424  EM=-0.0440  CD=  2.0215
   STATIONS 3-6   A=      0.0   B=  1.1094  ER=0.12533  EM=-0.1521  CD=  1.5853
   ALL STATIONS   A=      0.0   B=  1.3775  ER=0.16579  EM= 0.2412  CD=  2.0926

   STATIONS 1-4   A= 15997.3    B=  0.8558  ER=0.00419  EM=-0.0053
   STATIONS 2-5   A=  7537.1    B=  0.9005  ER=0.00759  EM=-0.0123
   STATIONS 3-6   A=  3879.2    B=  0.6168  ER=0.08029  EM=-0.0942
   ALL STATIONS   A=  3733.0    B=  1.0341  ER=0.07963  EM= 0.1434
```

SHOT 88 (8-07-77 ,NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=448. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.3670 KG LENGTH=0.152 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00033	0.00118	0.00315	0.00587	0.01298	0.02590	*******
NOSE POSITION (M)..							
X-COMP.	0.18110	0.17670	0.16872	0.13809	0.07339	-.16361	*******
Y-COMP.	0.12028	0.39831	0.82668	1.17253	1.66527	2.11357	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.18815	0.18832	0.16868	0.11549	-.14781	*******
Y-COMP.	*******	0.24550	0.67954	1.02803	1.52988	1.97191	*******
YAW ANGLE (DEG)....	-1.1	-3.9	-7.8	-11.2	-8.8	-3.5	0.0
C.G. POSITION (M)..							
X-COMP.	0.18402	0.18243	0.17852	0.15339	0.09444	-.15571	*******
Y-COMP.	0.04434	0.32191	0.75311	1.10028	1.59758	2.04274	*******

COEF. OF CUBIC POLYNOMIAL: -0.1491D-01 0.2817D 03 -0.1656D 05 0.3380D 06

FROM PONC. Y C.G. =	-0.02254	0.28455	0.75311	1.15608	1.71201	2.02277	********
ERROR (M)......	-0.06688	-0.03736	0.0	0.05580	0.11443	-0.01997	********
C.G. VY (M/S) =	423.	308.	187.	118.	51.	2.	

AT T=0.0. C.G. VY= 493. ; WHEN VY=0.0. T= 0.02674 AND Y= 2.02382

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 1.2766	ER=0.01089	EM=-0.0171	CD= 1.9392
STATIONS 2-5	A= 0.0	B= 1.2382	ER=0.01958	EM=-0.0250	CD= 1.8810
STATIONS 3-6	A= 0.0	B= 0.9083	ER=0.12628	EM=-0.1457	CD= 1.3798
ALL STATIONS	A= 0.0	B= 1.3022	ER=0.12201	EM=-0.1863	CD= 1.9782

STATIONS 1-4	A= 15986.8	B= 0.8652	ER=0.00419	EM=-0.0054
STATIONS 2-5	A= 4160.6	B= 1.0070	ER=0.00874	EM=-0.0141
STATIONS 3-6	A= 4258.2	B= 0.4284	ER=0.08317	EM=-0.1051
ALL STATIONS	A= 2963.0	B= 1.0077	ER=0.06705	EM= 0.1144

```
                        SHOT   89 ( 8-08-77 .NO. 1)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=450. M/S
      SOLID FLAT NOSE PROJECTILE ; MASS=0.3664 KG  LENGTH=0.152 M

X-RAY STATION.......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00034  0.00120  0.00274  0.00550  0.01058  0.02001  *******

NOSE POSITION (M)..
   X-COMP.          0.19872  0.19851  *******  *******  *******  *******  *******
   Y-COMP.          0.11450  0.41090  *******  *******  *******  *******  *******

TAIL POSITION (M)..
   X-COMP.          *******  0.17322  0.19025  0.24386  *******  *******  *******
   Y-COMP.          *******  0.23824  0.61665  0.97234  *******  *******  *******

YAW ANGLE (DEG)....    1.4      9.7      9.2     10.9      0.0      0.0      0.0

C.G. POSITION (M)..
   X-COMP.          0.18501  0.18587  0.21424  0.27208  *******  *******  *******
   Y-COMP.          0.03859  0.32457  0.68876  1.04290  *******  *******  *******

COEF. OF CUBIC POLYNOMIAL:    -0.9660D-01    0.4102D 03    -0.5336D 05    0.2992D 07

FROM FONC. Y C.G. = 0.03064  0.32457  0.68693  1.04056  1.11650 ******** ********
   ERROR (M)....... -0.00795  0.0    -0.00184 -0.00235 ******** ******** ********
   C.G. VY (M/S)  =    399.     295.     186.      81.    *****    5482.
   AT T=0.C.  C.G. VY= 460.       ;  WHEN  VY=0.0.  T= 0.00863  AND  Y= 1.16279

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=       0.0  B=   1.3969  ER=0.01773  EM=-0.0259  CD=  2.1185

   ALL STATIONS    A= 24027.0  B=   0.8248  ER=0.00490  EM=-0.0080
```

SHOT 90 (8-08-77 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=283. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.9198 KG LENGTH=0.381 M

X-RAY STATICN......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECCNDS).....	0.00044	0.00209	0.00531	0.00901	0.01509	0.03003	*******
NOSE POSITION (M)..							
X-COMP.	0.17048	0.17363	*******	*******	0.19904	*******	*******
Y-COMP.	0.07819	0.32065	*******	*******	1.67729	*******	*******
TAIL PCSITICN (M)..							
X-COMP.	*******	*******	0.17504	0.18001	0.18349	*******	*******
Y-COMP.	*******	*******	0.46973	0.86380	1.28939	*******	*******
YAW ANGLE (DEG)....	0.6	0.4	0.5	0.5	1.8	0.0	0.0
C.G. POSITICN (M)..							
X-COMP.	0.16649	0.17130	0.17836	0.18367	0.19127	*******	*******
Y-COMP.	-.11227	0.13036	0.66020	1.05426	1.48334	*******	*******

COEF. OF CUBIC POLYNOMIAL: -0.2063D 00 0.1841D 03 -0.4763D 04 -0.1430D 04

FROM PONC. Y C.G. =	-0.13C87	0.17058	0.66020	1.07992	1.47998	1.06765	********
ERROR (M)......	-0.01860	0.04022	0.0	0.02566	-0.00336	********	********
C.G. VY (M/S) =	194.	172.	133.	95.	38.	*****	

AT T=0.0. C.G. VY= 200. ; WHEN VY=0.0. T= 0.01945 AND Y= 1.56246

PONCELET CCEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.6969 ER=0.07182 EM= 0.1048 CD= 2.6534

ALL STATIONS A= 8639.2 B= 0.1431 ER=0.02566 EM= 0.0402

SHOT 91 (8-08-77 ,NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=417. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.7350 KG LENGTH=0.305 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00050	0.00215	0.00538	0.00906	0.01509	0.03006	*******
NOSE POSITION (M)..							
X-COMP.	0.16626	0.17055	0.17315	0.17575	0.18488	*******	*******
Y-COMP.	0.08186	0.39153	0.80091	1.18847	1.64320	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.16396	0.17408	0.18642	0.18861	0.17417	*******
Y-COMP.	*******	0.25373	0.48249	0.85521	1.34210	2.06065	*******
YAW ANGLE (DEG)....	0.3	-0.2	0.0	-1.8	-1.1	3.3	0.0
C.G. POSITION (M)..							
X-COMP.	0.16493	0.16726	0.17362	0.18109	0.18675	0.19143	*******
Y-COMP.	-.07063	0.32513	0.64170	1.02184	1.49265	2.21217	*******

COEF. OF CUBIC POLYNOMIAL: -0.1014D 00 0.1701D 03 -0.5570D 04 0.9227D 05

FROM PONC. Y C.G. =	-0.04416	0.21690	0.64170	1.02725	1.50650	2.21073	********
ERROR (M)......	0.02647	-0.10823	0.0	0.00541	0.01385	-0.00144	********
C.G. VY (M/S) =	169.	148.	117.	93.	67.	31.	

AT T=0.0, C.G. VY= 177. ; WHEN VY=0.0, T= 0.05040 AND Y= 2.50845

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 1.6573	ER=0.05069	EM= 0.0791	CD= 5.0423
STATIONS 2-5	A= 0.0	B= 0.0000	ER=0.04639	EM=-0.0757	CD= 0.0000
STATIONS 3-6	A= 0.0	B= 0.6813	ER=0.04466	EM= 0.0694	CD= 2.0728
ALL STATIONS	A= 0.0	B= 0.6875	ER=0.05626	EM=-0.1223	CD= 2.0917

STATIONS 1-4	A= 0.0	B= 1.6734	ER=0.05072	EM= 0.0781
STATIONS 2-5	A= 0.0	B= 1.6734	ER=0.34264	EM=-0.5219
STATIONS 3-6	A= 0.0	B= 1.6734	ER=0.45289	EM=-0.6922
ALL STATIONS	A= 1374.7	B= 0.4632	ER=0.05027	EM=-0.1082

```
                        SHOT  92 ( 9-08-77 .NO. 1)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=325. M/S
     HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6313 KG  LENGTH=0.306 M

X-RAY STATION......  NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00047   0.00212   0.00534   0.00905   0.01780   0.03006   *******

NOSE POSITION (M)..
    X-COMP.         *******   0.17237   0.18924   0.20102   0.22958   *******   *******
    Y-COMP.         *******   0.34405   0.77032   1.16873   1.61809   *******   *******

TAIL POSITION (M)..
    X-COMP.         *******   *******   *******   *******   *******   0.24841   *******
    Y-COMP.         *******   *******   *******   *******   *******   2.07307   *******

YAW ANGLE (DEG)....   0.0       0.9       1.5       3.6       3.9      -1.9       0.0

C.G. POSITION (M)..
    X-COMP.         *******   0.16928   0.18202   0.18372   0.21085   0.23728   *******
    Y-COMP.         *******   0.20611   0.63251   1.03182   1.48137   2.24070   *******

COEF. OF CUBIC POLYNOMIAL:  -0.1866D 00   0.1995D 03   -0.8810D 04   0.1617D 06

FROM POLY. Y C.G. =-0.24959  0.17779   0.67283   1.03182   1.54853   1.57946 ********
    ERROR (M)...... ******** -0.02832   0.04032   0.0       0.06757  -0.26124 ********
    C.G. VY (M/S)  =    330.      205.      119.       80.       45.       28.
    AT T=0.0.  C.G. VY= 397.      ;  WHEN  VY=0.0.  T=61.14763  AND  Y= 8.38593

PONCELET COEFFICIENTS BASED ON :

    ALL STATIONS   A=      0.0  B=  0.7385  ER=0.10552  EW=-0.1183  CD=  1.9298

    ALL STATIONS   A=      0.0  B=  1.1072  ER=0.13715  EM=-0.2612
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                         SHOT   93 ( 9-08-77 ,NO. 2)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=413. M/S
     SOLID STEP CONE PROJECTILE ; MASS=0.5110 KG  LENGTH=0.221 M

X-RAY STATION......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS).....  0.00048  0.00215  0.00536  0.00908  0.01509  0.03012  *******

NOSE POSITION (M)..
   X-COMP.           0.17177  *******  0.17238  0.16358  0.14426  *******  *******
   Y-COMP.           0.06456  *******  0.80135  1.16919  1.60202  *******  *******

TAIL POSITION (M)..
   X-COMP.           *******  0.16709  0.17464  0.17727  0.17743  0.09229  -.07160
   Y-COMP.           *******  0.17063  0.59713  0.96091  1.38960  2.10306  2.14256

YAW ANGLE (DEG)....   -1.4     -0.5      0.5     -2.1     -9.0     -7.3     -5.2

C.G. POSITION (M)..
   X-COMP.           0.17723  0.16544  0.17357  0.17077  0.16167  0.06600  -.09055
   Y-COMP.           -.05131  0.27562  0.69416  1.05987  1.49052  2.20472  2.24584

COEF. OF CUBIC POLYNOMIAL:  -0.1200D 00    0.1856D 03    -0.6925D 04    0.1104D 06

FROM PONC. Y C.G. =-0.06746  0.24060  0.69416  1.08348  1.53611  2.19810 ********
   ERROR (M)...... -0.01615 -0.03502  0.0      0.02361  0.04558 -0.00662 ********
   C.G. VY (M/S)  =   206.     166.     121.      91.      63.      30.
   AT T=0.0.  C.G. VY= 221.     :  WHEN  VY=0.0.  T= 0.06006  AND  Y= 2.60703

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4   A=     0.0  B=  0.9733  ER=0.00916  EM= 0.0150  CD=  2.0587
   STATIONS 2-5   A=     0.0  B=  0.7002  ER=0.00645  EM=-0.0077  CD=  1.4810
   STATIONS 3-6   A=     0.0  B=  0.6192  ER=0.03789  EM=-0.0439  CD=  1.3097
   ALL STATIONS   A=     0.0  B=  0.7983  ER=0.03612  EM=-0.0511  CD=  1.6986

   STATIONS 1-4   A=     0.0  B=  1.0047  ER=0.01027  EM= 0.0125
   STATIONS 2-5   A=     0.0  B=  1.0047  ER=0.09521  EM=-0.1433
   STATIONS 3-6   A=     0.0  B=  1.0047  ER=0.25453  EM=-0.3665
   ALL STATIONS   A=   833.1  B=  0.6628  ER=0.02887  EM= 0.0456
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                          SHOT   94 ( 9-08-77 ,NO. 3)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=187. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.9201 KG  LENGTH=0.381 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00050  0.00230  0.00561  0.01002  0.01814  0.03000  *******

NOSE POSITION (M)..
   X-COMP.          *******  0.16860  0.17470  0.18229  0.19276  0.20239  *******
   Y-COMP.          *******  0.27708  0.63625  1.03005  1.59834  2.17208  *******

TAIL POSITION (M)..
   X-COMP.          *******  *******  *******  *******  0.18622  0.18506  *******
   Y-COMP.          *******  *******  *******  *******  1.20339  1.81688  *******

YAW ANGLE (DEG)....   0.0      0.4      0.8      0.9      2.0      2.8      0.0

C.G. POSITION (M)..
   X-COMP.          *******  0.16594  0.16971  0.17631  0.18949  0.19373  *******
   Y-COMP.          *******  0.08660  0.44582  0.83964  1.40087  1.99448  *******

COEF. OF CUBIC POLYNOMIAL:   -0.1918D 00    0.1278D 03   -0.2777D 04    0.3158D 05

FROM FONC. Y C.G. =-0.14125  0.08260  0.44243  0.83964  1.40499  1.98187 ********
   ERROR (M)...... ******** -0.00399 -0.00338  0.0      0.00413 -0.01261 ********
   C.G. VY (M/S)  =    131.      118.     100.      82.      59.      39.
   AT T=0.0.  C.G. VY= 135.      :  WHEN  VY=0.0.  T= 0.07536  AND  Y= 2.77540

FONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=     0.0  B=  0.5451  ER=0.01201  EM=-0.0194  CD=  2.0759

   ALL STATIONS   A=   690.0  B=  0.4171  ER=0.00713  EM=-0.0126
```

SHOT 95 (9-08-77, NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=208. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.7365 KG LENGTH=0.305 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00047	0.00228	0.00561	0.00997	0.01806	0.02997	*******
NOSE POSITION (M)..							
X-COMP.	*******	*******	0.18739	0.19713	0.23012	*******	*******
Y-COMP.	*******	*******	0.64613	1.03906	1.55700	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	*******	*******	*******	0.20945
Y-COMP.	*******	*******	*******	*******	*******	*******	2.18957
YAW ANGLE (DEG)....	0.0	0.0	1.8	2.9	4.1	0.3	-3.9
C.G. POSITION (M)..							
X-COMP.	*******	*******	0.17808	0.18172	0.20837	*******	0.18875
Y-COMP.	*******	*******	0.49391	0.83734	1.40606	*******	2.34066

SHOT 96 (9-08-77 ,NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=209. M/S
HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6313 KG LENGTH=0.306 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00050	0.00381	0.00702	0.01197	0.01806	0.02997	*******
NOSE POSITION (M)..							
X-COMP.	0.17869	0.17976	0.18812	0.20187	0.22352	0.22605	*******
Y-COMP.	0.06765	0.45715	0.80522	1.19487	1.54049	2.03548	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.16960	*******	*******	*******	*******	*******
Y-COMP.	*******	0.11224	*******	*******	*******	*******	*******
YAW ANGLE (DEG)....	1.2	2.6	2.1	2.7	2.3	1.7	0.0
C.G. POSITION (M)..							
X-COMP.	0.17315	0.17518	0.17801	0.18912	0.21245	0.21787	*******
Y-COMP.	-.07024	0.30160	0.66759	1.05746	1.40293	1.89772	*******

COEF. OF CUBIC POLYNOMIAL: -0.1472D 00 0.1375D 03 -0.3655D 04 0.4478D 05

FROM PONC. Y C.G. =	-0.09032	0.33714	0.66759	1.06717	1.43390	1.89099	********
ERROR (M)......	-0.02008	0.03554	0.0	0.00971	0.03056	-0.00673	********
C.G. VY (M/S) =	146.	114.	93.	70.	51.	27.	

AT T=0.0, C.G. VY= 153. ; WHEN VY=0.0, T= 0.04996 AND Y= 2.15163

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.4998	ER=0.03989	EM=-0.0603	CD= 1.3060
STATIONS 2-5	A= 0.0	B= 0.8957	ER=0.00402	EM=-0.0065	CD= 2.3405
STATIONS 3-6	A= 0.0	B= 0.6642	ER=0.04139	EM=-0.0464	CD= 1.7356
ALL STATIONS	A= 0.0	B= 0.7592	ER=0.04018	EM=-0.0732	CD= 1.9840

STATIONS 1-4	A= 5737.0	B= 0.0004	ER=0.03051	EM=-0.0483
STATIONS 2-5	A= 7471.1	B= 0.0455	ER=0.03504	EM= 0.0542
STATIONS 3-6	A= 1627.7	B= 0.3708	ER=0.02723	EM=-0.0387
ALL STATIONS	A= 1248.1	B= 0.5068	ER=0.02351	EM= 0.0355

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                         SHOT   97 (10-08-77 ,NO. 1)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=152. M/S
      SOLID FLAT NOSE PROJECTILE ; MASS=0.9202 KG  LENGTH=0.381 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00050   0.00351   0.00702   0.01201   0.01805   0.03016   *******

NOSE POSITION (M)..
   X-COMP.          0.17314   0.17145   0.18210   0.18444   *******   0.20496   *******
   Y-COMP.          0.03777   0.33406   0.59948   0.96702   *******   1.85934   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.17120   *******   *******   *******   *******   *******
   Y-COMP.          *******   0.09466   *******   *******   *******   *******   *******

YAW ANGLE (DEG)....   1.9       0.1       0.8       0.5       0.0       0.8       0.0

C.G. POSITION (M)..
   X-COMP.          0.16051   0.17133   0.17711   0.18078   *******   0.19964   *******
   Y-COMP.          -.15231   0.21436   0.40905   0.77656   *******   1.66891   *******

COEF. OF CUBIC POLYNOMIAL:    -0.1915D 00    0.1141D 03    -0.3633D 04    0.6288D 05

FROM PONC. Y C.G. =-0.12566   0.13824   0.40905   0.74247   1.08537   1.63928 ********
   ERROR (M)......  0.02665 -0.07612   0.0      -0.03409 ******** -0.02963 ********
   C.G. VY (M/S)  =     93.       82.       72.       62.       52.       40.
   AT T=0.0.  C.G. VY=  96.      ;  WHEN  VY=0.0.  T=********  AND  Y=19.89415

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=      0.0  B=  0.4335  ER=0.04378  EM=-0.0744  CD=  1.6511

   ALL STATIONS    A=      0.0  B=  0.4780  ER=0.04622  EM=-0.0761
```

SHOT 98 (10-08-77 ,NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=134. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.7356 KG LENGTH=0.305 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00055	0.00357	0.00709	0.01208	0.01809	0.03012	*******
NOSE POSITION (M)..							
X-COMP.	*******	0.17638	0.18262	0.19896	*******	*******	*******
Y-COMP.	*******	0.34439	0.63256	0.95708	*******	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	*******	*******	*******	*******
Y-COMP.	*******	*******	*******	*******	*******	*******	*******
YAW ANGLE (DEG)....	0.0	0.5	1.3	3.4	0.0	0.0	0.0
C.G. POSITION (M)..							
X-COMP.	*******	0.17372	0.17570	0.18090	*******	*******	*******
Y-COMP.	*******	0.19191	0.48022	0.80565	*******	*******	*******

SHOT 94 (10-08-77 .NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=186. M/S
HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6322 KG LENGTH=0.306 M

```
X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00090   0.00452   0.00904   0.01502   0.02406   0.03705   *******

NOSE POSITION (M)..
   X-COMP.          0.16783   0.16787   0.17309   0.17754   0.18814   0.19203   *******
   Y-COMP.          0.10839   0.50894   0.88464   1.26584   1.67023   2.06674   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.17330   0.18038   0.17196   0.17007   0.18398   0.22549
   Y-COMP.          *******   0.20369   0.56867   0.94583   1.35535   1.81552   2.19400

YAW ANGLE (DEG)....   -0.9      -1.4      -0.7       1.8       3.4       1.6      -2.3

C.G. POSITION (M)..
   X-COMP.          0.17173   0.17032   0.17638   0.17502   0.17999   0.18840   0.21202
   Y-COMP.          -.02956   0.37128   0.74214   1.12152   1.52823   1.95344   2.30140

COEF. OF CUBIC POLYNOMIAL:    -0.1284D 00    0.1203D 03    -0.2919D 04    0.3209D 05

FROM PONC. Y C.G. =-0.03945   0.35540   0.74214   1.13322   1.55838   1.94546 ********
   ERROR (M)....... -0.00989 -0.01588   0.0       0.01169   0.03016 -0.00799 ********
   C.G. VY (M/S)  =    123.       97.       75.       57.       39.       22.
   AT T=0.0. C.G. VY= 132.     ; WHEN  VY=0.0.  T= 0.06251  AND  Y= 2.21280

FORCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0   B=   0.7537  ER=0.00287  EM= 0.0047  CD=  1.9724
   STATIONS 2-5    A=      0.0   B=   0.6857  ER=0.01011  EM=-0.0142  CD=  1.7945
   STATIONS 3-6    A=      0.0   B=   0.7007  ER=0.01757  EM=-0.0237  CD=  1.8338
   ALL STATIONS    A=      0.0   B=   0.7770  ER=0.03701  EM=-0.0630  CD=  2.0332

   STATIONS 1-4    A=    693.3   B=   0.6414  ER=0.00402  EM= 0.0061
   STATIONS 2-5    A=   1286.6   B=   0.4152  ER=0.00254  EM=-0.0034
   STATIONS 3-6    A=    529.8   B=   0.5474  ER=0.00844  EM=-0.0057
   ALL STATIONS    A=    786.0   B=   0.5413  ER=0.01709  EM= 0.0302
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                              SHOT 101 (10-08-77 ,NO. 5)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY= 99. M/S
      HOLLOW FLAT NOSE PROJECTILE ; MASS=0.0321 KG  LENGTH=0.306 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00094   0.00504   0.01056   0.01707   0.02701   0.04503   *******

NOSE POSITION (M)..
   X-COMP.          0.16870   *******   0.17494   0.18056   *******   *******   *******
   Y-COMP.          0.07467   *******   0.68744   0.97835   *******   *******   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.17147   *******   *******   *******   *******   0.18970
   Y-COMP.          *******   0.10234   *******   *******   *******   *******   2.08310

YAW ANGLE (DEG)....   -0.6      -0.4       0.3       0.9       0.0       0.0       0.5

C.G. POSITION (M)..
   X-COMP.          0.17183   0.16912   0.17374   0.17647   *******   *******   0.19234
   Y-COMP.          -.06329   0.27032   0.54945   0.84041   *******   *******   2.25108

COEF. OF CUBIC POLYNOMIAL:    -0.1630D 00    0.1118D 03   -0.5970D 04    0.1678D 06

FROM PONC. Y C.G. =-0.04473   0.27032   0.56821   0.82360   1.10784   1.45979 ********
   ERROR (M)......  0.01857   0.0       0.01876 -0.01681 ******** ******** ********
   C.G. VY (M/S)  =    93.       64.       46.       34.       24.       16.
   AT T=0.0.  C.G. VY= 103.      ; WHEN  VY=0.0.   T= 0.29258  AND  Y= 2.58420

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=      0.0  B=  1.1384  ER=0.01789  EM= 0.0194  CD=  2.9786

   ALL STATIONS   A=     23.7  B=  1.1463  ER=0.01807  EM= 0.0188
```

SHOT 102 (10-08-77 ... 6)

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DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=452. M/S
SOLID FLAT NOSE PROJECTILE : MASS=0.3668 KG  LENGTH=0.152 M

X-RAY STATICN......    NC.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECCNDS)..... 0. 0034   0.00120   0.00274   0.00550   0.01065   0.02003   *******

NOSE POSITICN (M)..
   X-COMP.           0.16941   0.17535   *******   0.25183   *******   0.24192   0.21017
   Y-CCMP.           0.11640   0.40424   *******   1.16197   *******   1.83133   2.22613

TAIL PCSITICN (M)..
   X-COMP.           *******   0.15876   0.16868   0.21054   0.23320   *******   0.23720
   Y-COMP.           *******   0.25058   0.61956   1.02047   1.36762   *******   2.08172

YAW ANGLE (DEG)....    1.4       4.4       5.6      16.3       1.2       4.3      -7.7

C.G. PCSITICN (M)..
   X-COMP.           0.16583   0.16766   0.18331   0.23119   0.23625   0.23056   0.22369
   Y-COMP.           0.04048   0.32741   0.69414   1.09122   1.44356   1.75618   2.15393

COEF. OF CUBIC POLYNCMIAL:   -0.4596D-01    0.3235D 03    -0.2372D 05    0.6022D 06

FRCM FCNC. Y C.G. =-0.02408  0.29877   0.69414   1.12792   1.54947   1.73628  ********
   ERROR (M)...... -0.06457 -0.02864   0.0       0.03670   0.10591  -0.01991  ********
   C.G. VY (M/S)  =    450.     320.      207.      120.       53.     *****
   AT T=0.0.  C.G. VY= 535.      :  WHEN  VY=0.0.   T= 0.01849  AND   Y= 1.74329

FONCELET CCEFFICIENTS EASED ON :

   STATIONS 1-4    A=      0.0  B=   1.2199  ER=0.00947  EM=-0.0153  CD=  1.8521
   STATIONS 2-5    A=      0.0  B=   1.3177  ER=0.03154  EM=-0.0429  CD=  2.0007
   STATICNS 3-6    A=      0.0  B=   1.2118  ER=0.09943  EM=-0.1226  CD=  1.8398
   ALL STATIONS    A=      0.0  B=   1.4203  ER=0.14135  EM= 0.2095  CD=  2.1565

   STATICNS 1-4    A=  14345.8  B=   0.8906  ER=0.00367  EM=-0.0057
   STATIONS 2-5    A=  11301.3  B=   0.8190  ER=0.00494  EM=-0.0082
   STATICNS 3-6    A=   5784.4  B=   0.6843  ER=0.05381  EM=-0.0606
   ALL STATIONS    A=   5906.6  B=   1.0109  ER=0.05992  EM= 0.1059
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                         SHOT 103 (11-08-77 ,NO. 1)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=149. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.9193 KG  LENGTH=0.381 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00091   0.00502   0.01061   0.01710   0.02715   0.04509   *******

NOSE POSITION (M)..
   X-COMP.          0.17200   0.17992   *******   *******   0.21478   0.22166   *******
   Y-COMP.          0.08143   0.39774   *******   *******   1.57746   2.14746   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.16089   *******   0.17819   0.19026   0.21298   *******
   Y-COMP.          *******   0.06982   *******   0.71820   1.28394   1.80904   *******

YAW ANGLE (DEG)....   1.1       3.2       0.0       2.4       4.5       1.2       0.0

C.G. POSITION (M)..
   X-COMP.          0.16502   0.17041   *******   0.19380   0.20252   0.21732   *******
   Y-COMP.          -.10894   0.23378   *******   0.90806   1.43070   1.97825   *******

COEF. OF CUBIC POLYNOMIAL:     -0.1563D 00    0.7393D 02    -0.5505D 03    0.3254D 02

FROM PONC. Y C.G. =-0.10357  0.17977  0.53690  0.90806  1.39415  1.99119 ********
   ERROR (M)......  0.00537 -0.05401 ********  0.0     -0.03655  0.01293 ********
   C.G. VY (M/S)  =    71.       67.       61.       54.       43.       24.
   AT T=0.0.  C.G. VY=  72.      ;  WHEN  VY=0.0.  T= 0.06702  AND  Y= 2.24995

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=      0.0  B=  0.4013  ER=0.07363  EM= 0.1075  CD=  1.5269

   ALL STATIONS    A=   1076.7  B=  0.0005  ER=0.03335  EM=-0.0540
```

SHOT 104 (11-08-77 ,NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=169. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.7369 KG LENGTH=0.305 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00090	0.00501	0.01061	0.01708	0.02711	0.04503	*******
NOSE POSITION (M)..							
X-COMP.	0.17409	0.17602	0.18512	0.19206	0.19897	0.20603	*******
Y-COMP.	0.08205	0.43292	0.81292	1.16485	1.56686	2.09201	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.16875	0.16873	0.17227	0.17922	0.20478	*******
Y-COMP.	*******	0.09574	0.47153	0.88362	1.27852	1.79994	*******
YAW ANGLE (DEG)....	0.2	2.3	3.9	5.1	2.7	0.4	0.0
C.G. POSITION (M)..							
X-COMP.	0.17303	0.17239	0.17693	0.18217	0.18910	0.20541	*******
Y-COMP.	-.07045	0.26433	0.64223	1.02424	1.42269	1.94598	*******

COEF. OF CUBIC POLYNOMIAL: -0.1528D 00 0.9062D 02 -0.1518D 04 0.1200D 05

FROM FCNC. Y C.G. =	-0.07755	0.25687	0.64223	1.00671	1.44396	1.54192	********
ERROR (M)......	-0.00711	-0.00746	0.0	-0.01753	0.02127	-0.00405	********
C.G. VY (M/S) =	88.	76.	62.	51.	37.	20.	

AT T=0.0. C.G. VY= 91. ; WHEN VY=0.0. T= 0.07109 AND Y= 2.18874

FONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.4418	ER=0.00508	EM= 0.0064	CD= 1.3476
STATIONS 2-5	A= 0.0	B= 0.4392	ER=0.02903	EM=-0.0434	CD= 1.3397
STATIONS 3-6	A= 0.0	B= 0.8378	ER=0.03062	EM= 0.0449	CD= 2.5556
ALL STATIONS	A= 0.0	B= 0.6590	ER=0.03486	EM=-0.0619	CD= 2.0102

STATIONS 1-4	A= 0.0	B= 0.4415	ER=0.00508	EM= 0.0064
STATIONS 2-5	A= 1524.9	B= 0.0015	ER=0.01891	EM=-0.0294
STATIONS 3-6	A= 0.0	B= 0.8739	ER=0.03767	EM=-0.0494
ALL STATIONS	A= 706.8	B= 0.3440	ER=0.01328	EM= 0.0213

SHOT 106 (11-08-77 ,NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=478. M/S
SOLID STEP CONE PROJECTILE ; MASS=0.5107 KG LENGTH=0.221 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	C.00048	0.00212	0.00535	0.00907	*******	0.03009	*******
NOSE POSITION (M)..							
X-COMP.	0.17633	*******	0.22347	*******	*******	0.19957	*******
Y-COMP.	0.07483	*******	0.78741	*******	*******	1.97505	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.15781	0.16932	0.24877	*******	0.04351	C.17298
Y-COMP.	*******	0.13133	0.59330	0.91825	*******	1.77663	2.14073
YAW ANGLE (DEG)....	-0.1	2.7	15.3	0.5	0.0	-10.7	-5.5
C.G. POSITION (M)..							
X-COMP.	0.17673	0.16751	0.19505	0.25079	*******	0.11766	0.15295
Y-COMP.	-.04117	0.23588	0.68552	1.02323	*******	1.87090	2.24380

COEF. OF CUBIC POLYNOMIAL: -0.1351D 00 0.1958D 03 -0.8868D 04 0.1521D 06

FROM FONC. Y C.G. =	-0.04868	0.24843	0.68552	1.04563	-0.14824	1.87018	********
ERROR (M)......	-0.00751	0.01255	0.0	0.02240	********	-0.00072	********
C.G. VY (M/S) =	202.	162.	114.	82.	*****	10.	

AT T=0.C. C.G. VY= 217. ; WHEN VY=0.0. T= 0.03484 AND Y= 1.89397

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 1.0769 ER=0.08209 EM=-0.1196 CD= 2.2766

ALL STATIONS A= 2100.4 B= 0.6849 ER=0.01338 EM= 0.0224

SHOT 107 (11-08-77 ,NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=463. M/S
SOLID STEP CONE PROJECTILE ; MASS=0.5107 KG LENGTH=0.221 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00042	0.00208	0.00529	0.00901	0.01498	0.02877	*******
NOSE POSITION (M)..							
X-COMP.	0.16553	*******	0.13990	0.06975	*******	*******	0.03896
Y-COMP.	0.06440	*******	0.77890	1.10486	*******	*******	1.93784
TAIL POSITION (M)..							
X-COMP.	*******	0.17819	0.18703	0.14954	*******	*******	0.02398
Y-COMP.	*******	0.14411	0.58152	0.91074	*******	*******	1.80696
YAW ANGLE (DEG)....	-0.9	-2.3	-13.5	-11.6	0.0	0.0	4.3
C.G. POSITION (M)..							
X-COMP.	0.16917	0.16995	0.16464	0.11163	*******	*******	0.03110
Y-COMP.	-.05154	0.24879	0.67530	1.00297	*******	*******	1.86914

COEF. OF CUBIC POLYNOMIAL: -0.1374D 00 0.2099D 03 -0.1259D 05 0.3704D 06

FROM FCNC. Y C.G. =	-0.05484	0.24879	0.67622	1.00441	1.28422	1.06274	********
ERROR (M)......	-0.00330	0.0	0.00092	0.00144	********	********	********
C.G. VY (M/S) =	205.	162.	109.	70.	26.	*****	

AT T=0.0. C.G. VY= 219. ; WHEN VY=0.0, T= 0.01933 AND Y= 1.34058

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.9724 ER=0.00880 EM=-0.0131 CD= 2.0555

ALL STATIONS A= 5899.1 B= 0.5922 ER=0.00214 EM=-0.0033

SHOT 103 (11-08-77 ,NO. 6)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=147. M/S
HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6324 KG LENGTH=0.306 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00148	0.00995	0.02505	0.03997	0.06994	0.09991	*******
NOSE POSITION (M)..							
X-COMP.	0.17579	*******	*******	*******	*******	*******	*******
Y-COMP.	0.15911	*******	*******	*******	*******	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.17949	*******	*******	*******	*******	0.22262
Y-COMP.	*******	0.52400	*******	*******	*******	*******	2.07640
YAW ANGLE (DEG)....	-0.2	0.4	0.0	0.0	0.0	0.0	-2.3
C.G. POSITION (M)..							
X-COMP.	0.17675	0.18154	*******	*******	*******	*******	0.20915
Y-COMP.	0.02111	0.69199	*******	*******	*******	*******	2.24386

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                         SHOT 109 (11-08-77 .NO. 7)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=447. M/S
     SOLID STEP CONE PROJECTILE ; MASS=0.5113 KG  LENGTH=0.221 M

X-RAY STATION......     NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00047  0.00258  0.00534  0.01003  0.01498  0.02702  *******

NOSE POSITION (M)..
   X-COMP.          *******  0.18456  0.20979  0.25214  0.23757  0.18539  *******
   Y-COMP.          *******  0.43225  0.78518  1.20772  1.48408  1.93165  *******

TAIL POSITION (M)..
   X-COMP.          *******  *******  0.17453  0.23340  *******  *******  0.15756
   Y-COMP.          *******  *******  0.57395  1.00463  *******  *******  2.08324

YAW ANGLE (DEG)....     0.0      5.4      9.0      4.5     -2.1     -5.0     -6.9

C.G. POSITION (M)..
   X-COMP.          *******  0.17324  0.19128  0.24230  0.24586  0.20533  0.13269
   Y-COMP.          *******  0.31680  0.67431  1.10112  1.36838  1.81738  2.18525

COEF. OF CUBIC POLYNOMIAL:   -0.1110D 00    0.1844D 03   -0.7629D 04    0.1275D 06

FROM PONC. Y C.G. =-0.15182  0.30639  0.68688  1.10112  1.38846  1.80063 ********
   ERROR (M)...... ******** -0.01041  0.01258  0.0      0.02009 -0.01675 ********
   C.G. VY (M/S)  =   280.     171.     113.      70.      48.      24.
   AT T=0.C.  C.G. VY= 326.      ;  WHEN  VY=0.0.  T= 0.05286  AND  Y= 2.07698

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=     0.0  B=   1.1691  ER=0.02141  EM= 0.0282  CD=  2.4744

   ALL STATIONS    A=   750.5  B=   1.0578  ER=0.01541  EM= 0.0201
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                         SHOT 110 (14-09-77 ,NO. 1)

   DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=186. M/S
   HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6357 KG  LENGTH=0.306 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS).....  0.00147   0.00479   0.00980   0.01653   0.02592   0.04099   *******

NOSE POSITION (M)..
    X-COMP.          0.17423   0.18018   0.19168   0.20651   0.22925   0.23310   *******
    Y-COMP.          0.17135   0.50124   0.88289   1.27576   1.66312   2.07828   *******

TAIL POSITION (M)..
    X-COMP.          *******   0.16271   0.15966   0.17290   0.19440   0.22920   0.23641
    Y-COMP.          *******   0.19651   0.58474   0.96888   1.37263   1.78126   2.09415

YAW ANGLE (DEG)....    0.4       2.8       5.7       5.8       4.9       0.5      -2.0

C.G. POSITION (M)..
    X-COMP.          0.17254   0.17230   0.17724   0.19135   0.21353   0.23134   0.22498
    Y-COMP.          0.03336   0.36381   0.74843   1.13736   1.53211   1.94433   2.26176

COEF. OF CUBIC POLYNOMIAL:    -0.1137D 00     0.1080D 03    -0.2265D 04     0.2088D 05

FROM POLY. Y C.G. = 0.02352   0.35183   0.74843   1.15187   1.55316   1.93894 ********
    ERROR (M)...... -0.00984 -0.01199   0.0       0.01451   0.02105 -0.00539 ********
    C.G. VY (M/S)  =    109.       90.       70.       52.       35.       17.
    AT T=0.C.   C.G. VY= 120.       ;  WHEN  VY=0.0.   T= 0.06091   AND   Y= 2.10684

PONCELET COEFFICIENTS BASED ON :

    STATIONS 1-4    A=      0.0   B=   0.7463  ER=0.00244  EM=-0.0039  CD=  1.9637
    STATIONS 2-5    A=      0.0   B=   0.7067  ER=0.00662  EM=-0.0084  CD=  1.8595
    STATIONS 3-6    A=      0.0   B=   0.6558  ER=0.04372  EM=-0.0469  CD=  1.7256
    ALL STATIONS    A=      0.0   B=   0.8229  ER=0.04176  EM=-0.0734  CD=  2.1652

    STATIONS 1-4    A=    688.7   B=   0.6180  ER=0.00196  EM= 0.0032
    STATIONS 2-5    A=    620.7   B=   0.5520  ER=0.00170  EM=-0.0026
    STATIONS 3-6    A=   1115.3   B=   0.2740  ER=0.01465  EM=-0.0202
    ALL STATIONS    A=    822.4   B=   0.5112  ER=0.01359  EM= 0.0210
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SHOT 111 (14-09-77 .NO. 2)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=130. M/S
HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6338 KG LENGTH=0.306 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00147	0.00479	0.00981	0.01652	0.02555	0.04081	*******
NOSE POSITION (M)..							
X-COMP.	0.17001	0.17106	0.17909	0.18511	0.19715	0.20331	*******
Y-COMP.	0.15410	0.45267	0.80927	1.18306	1.55738	1.97977	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.16624	*******	*******	0.18204	0.19223	0.20294
Y-COMP.	*******	0.14113	*******	*******	1.27750	1.78095	2.10476
YAW ANGLE (DEG)....	0.1	0.5	0.7	1.1	3.0	4.1	0.5
C.G. POSITION (M)..							
X-COMP.	0.16953	0.16889	0.17572	0.17981	0.19034	0.19831	0.20587
Y-COMP.	0.01610	0.31217	0.67131	1.04516	1.43116	1.89011	2.27273

COEF. OF CUBIC POLYNOMIAL: -0.1213D 00 0.9853D 02 -0.1998D 04 0.1939D 05

FROM PONC. Y C.G. =	0.00562	0.30489	0.67131	1.05233	1.45307	1.88295	********
ERROR (M)......	-0.01048	-0.00728	0.0	0.00716	0.02191	-0.00715	********
C.G. VY (M/S) =	99.	82.	65.	50.	36.	23.	

AT T=0.0. C.G. VY= 108. ; WHEN VY=0.0. T= 0.08615 AND Y= 2.35338

FORCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.6726	ER=0.00233	EM= 0.0033	CD=	1.7644
STATIONS 2-5	A= 0.0	B= 0.6738	ER=0.00727	EM=-0.0099	CD=	1.7676
STATIONS 3-6	A= 0.0	B= 0.6628	ER=0.01350	EM=-0.0185	CD=	1.7389
ALL STATIONS	A= 0.0	B= 0.7404	ER=0.02010	EM=-0.0373	CD=	1.9425

STATIONS 1-4	A= 402.2	B= 0.5988	ER=0.00103	EM= 0.0015
STATIONS 2-5	A= 426.1	B= 0.5567	ER=0.00387	EM=-0.0052
STATIONS 3-6	A= 315.0	B= 0.5474	ER=0.00824	EM=-0.0089
ALL STATIONS	A= 418.5	B= 0.5649	ER=0.01221	EM= 0.0219

SHOT 112 (14-09-77 ,NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY= 68. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.7354 KG LENGTH=0.305 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00146	0.00478	0.00979	0.01649	0.02592	0.04068	*******
NOSE POSITION (M)..							
X-COMP.	0.17342	0.16507	*******	*******	*******	*******	*******
Y-COMP.	0.05488	0.23217	*******	*******	*******	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	*******	*******	*******	0.15951
Y-COMP.	*******	*******	*******	*******	*******	*******	2.02116
YAW ANGLE (DEG)....	-1.6	-1.6	0.0	0.0	0.0	0.0	-0.1
C.G. POSITION (M)..							
X-COMP.	0.15167	0.17358	*******	*******	*******	*******	0.15898
Y-COMP.	-.09740	0.07991	*******	*******	*******	*******	2.17366

SHOT 113 (14-09-77 ,NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=109. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.7354 KG LENGTH=0.305 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS)......	0.00146	0.00478	0.00979	0.01646	0.02590	0.04059	*******
NOSE POSITION (M)..							
X-COMP.	0.17288	*******	0.18556	0.19590	0.21059	*******	*******
Y-COMP.	0.11558	*******	0.67031	1.00406	1.37552	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	*******	*******	*******	0.22367
Y-COMP.	*******	*******	*******	*******	*******	*******	2.10417
YAW ANGLE (DEG).....	-0.2	1.0	2.2	2.4	2.9	0.0	-1.3
C.G. POSITION (M)..							
X-COMP.	0.17394	*******	0.17386	0.18314	0.19544	*******	0.21675
Y-COMP.	-.03692	*******	0.51826	0.85209	1.22377	*******	2.25651

COEF. OF CUBIC POLYNOMIAL: -0.1543D 00 0.8273D 02 -0.1611D 04 0.1817D 05

FROM PONC. Y C.G. =	-0.04418	0.20493	0.51826	0.85069	1.20361	1.56278	********
ERROR (M)......	-0.00727	********	0.0	-0.00141	-0.02016	********	********
C.G. VY (M/S) =	81.	69.	56.	44.	32.	18.	

AT T=0.0. C.G. VY= 87. ; WHEN VY=0.0. T= 0.06866 AND Y= 1.83743

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.6630 ER=0.00590 EM=-0.0079 CD= 2.0181

ALL STATIONS A= 595.6 B= 0.5103 ER=0.01240 EM=-0.0202

SHOT 114 (14-09-77 ,NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 : APPROACH VELOCITY=329. M/S
SOLID STEP TIER PROJECTILE : MASS=0.5156 KG LENGTH=0.219 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00043	0.00263	0.00650	0.01151	0.01706	0.03016	*******
NOSE POSITION (M)..							
X-COMP.	*******	0.16993	0.18858	0.22146	0.25007	0.23170	*******
Y-COMP.	*******	0.39449	0.80465	1.18346	1.47578	1.55453	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.15831	0.15367	0.17027	0.22394	*******	0.23268
Y-COMP.	*******	0.18067	0.60173	0.97460	1.29648	*******	2.10988
YAW ANGLE (DEG)....	0.0	2.0	9.1	14.3	4.6	0.7	-0.9
C.G. POSITION (M)..							
X-COMP.	*******	0.16399	0.17075	0.19531	0.23672	0.22497	0.22931
Y-COMP.	*******	0.28527	0.70100	1.07678	1.38419	1.74670	2.21696

COEF. OF CUBIC POLYNOMIAL: -0.56770-01 0.13930 03 -0.39940 04 0.45050 05

FROM FCNC. Y C.G. =	-0.01267	0.28710	0.68962	1.07678	1.38029	1.74441	********
ERROR (M)......	********	0.00183	-0.01138	0.0	-0.00390	-0.00229	********
C.G. VY (M/S) =	147.	121.	91.	65.	45.	12.	

AT T=0.0. C.G. VY= 153. ; WHEN VY=0.0, T= 0.03618 AND Y= 1.78179

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.9897 ER=0.07212 EM= 0.1289 CC= 2.1122

ALL STATIONS A= 2047.2 B= 0.5203 ER=0.00619 EM=-0.0114

SHOT 115 (14-09-77 ,NO. 6)

DRY SAND- DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=346. M/S
SOLID STEP TIER PROJECTILE ; MASS=0.5155 KG LENGTH=0.219 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00069	0.00258	0.00650	0.01151	0.01902	0.03522	*******
NOSE POSITION (M)..							
X-COMP.	0.16389	0.16442	0.17035	0.16698	0.16131	0.13466	*******
Y-COMP.	0.09342	0.41670	0.78467	1.17286	1.55366	2.08572	*******
TAIL POSITION (M)..							
X-COMP.	*******	0.16255	0.17693	0.19356	0.17768	0.14671	0.11675
Y-COMP.	*******	0.21266	0.57130	0.96115	1.34305	1.86025	2.17114
YAW ANGLE (DEG)....	0.4	0.2	-1.6	-7.9	-5.2	-4.2	-0.3
C.G. POSITION (M)..							
X-COMP.	0.16252	0.16346	0.17371	0.18056	0.16967	0.14082	0.11582
Y-COMP.	-.01844	0.31248	0.67568	1.06472	1.44608	1.97056	2.27827

COEF. OF CUBIC POLYNOMIAL: -0.1075D 00 0.1484D 03 -0.4677D 04 0.6071D 05

FROM PONC. Y C.G. =	-0.04131	0.26826	0.67568	1.07862	1.49277	1.96255	********
ERROR (M)......	-0.02287	-0.02422	0.0	0.01390	0.04669	-0.00800	********
C.G. VY (M/S) =	162.	128.	95.	68.	44.	17.	

AT T=0.0. C.G. VY= 175. ; WHEN VY=0.0. T= 0.04929 AND Y= 2.07609

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.8847	ER=0.00478	EM= 0.0080	CD= 1.3879
STATIONS 2-5	A= 0.0	B= 0.7801	ER=0.01580	EM=-0.0225	CD= 1.6646
STATIONS 3-6	A= 0.0	B= 0.8388	ER=0.03093	EM=-0.0399	CD= 1.7898
ALL STATIONS	A= 0.0	B= 0.9483	ER=0.05287	EM=-0.0926	CD= 2.0235

STATIONS 1-4	A= 0.0	B= 0.8844	ER=0.00478	EM= 0.0080
STATIONS 2-5	A= 0.0	B= 0.8844	ER=0.03516	EM=-0.0448
STATIONS 3-6	A= 0.0	B= 0.8844	ER=0.04123	EM=-0.0493
ALL STATIONS	A= 1118.4	B= 0.6611	ER=0.02663	EM= 0.0467

```
                         SHOT 116 (14-09-77 .NO. 7)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=439. M/S
     SOLID STEP CONE PROJECTILE : MASS=0.5110 KG  LENGTH=0.221 M

X-RAY STATION......     NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00068   0.00295   0.00649   0.01148   0.01856   0.03516   *******

NOSE POSITION (M)..
   X-COMP.          0.16187   0.15920   0.14414   0.07283   *******   -.15037   *******
   Y-COMP.          0.09613   0.43948   0.84112   1.26073   *******   2.09562   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.16889   0.18273   0.14438   0.03982   0.01166   0.00994
   Y-COMP.          *******   0.23206   0.63906   1.05654   1.45124   1.83733   2.12208

YAW ANGLE (DEG)....     0.1      -2.3     -10.0     -19.3      -5.5       6.9       6.1

C.G. POSITION (M)..
   X-COMP.          0.16147   0.16429   0.16440   0.11039   0.01979   -.06532   0.03195
   Y-COMP.          -.01937   0.33061   0.73506   1.15355   1.55431   1.98629   2.22475

COEF. OF CUBIC POLYNOMIAL:    -0.1174D 00    0.1611D 03    -0.5008D 04    0.6050D 05

FROM FCNC. Y C.G. =-0.04376   0.30971   0.73506   1.16885   1.59742   1.97926 ********
   ERROR (M)...... -0.02389 -0.02090   0.0       0.01530   0.04311 -0.00703 ********
   C.G. VY (M/S)  =    174.      139.      104.       73.       44.        6.
   AT T=0.0.  C.G. VY= 188.      ;  WHEN  VY=0.0.  T= 0.03808  AND  Y= 1.98778

FONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0  B=   0.7931  ER=0.00332  EM=-0.0043  CD=  1.6775
   STATIONS 2-5    A=      0.0  B=   0.7671  ER=0.01848  EM=-0.0259  CD=  1.6225
   STATIONS 3-6    A=      0.0  B=   0.8744  ER=0.07340  EM=-0.0763  CD=  1.8494
   ALL STATIONS    A=      0.0  B=   0.9796  ER=0.09756  EM=-0.1569  CD=  2.0720

   STATIONS 1-4    A=   1303.8  B=   0.6925  ER=0.00386  EM= 0.0048
   STATIONS 2-5    A=   2998.9  B=   0.4085  ER=0.00270  EM=-0.0028
   STATIONS 3-6    A=   1938.5  B=   0.4554  ER=0.01601  EM=-0.0182
   ALL STATIONS    A=   1985.6  B=   0.5535  ER=0.02510  EM= 0.0431
```

SHOT 117 (15-09-77 , NO. 1)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=392. M/S
HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6357 KG LENGTH=0.306 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00150	0.00480	0.00984	0.01655	0.02596	0.04109	*******
NOSE POSITION (M)..							
X-COMP.	0.17292	0.17408	0.17734	0.18084	0.18704	0.18929	*******
Y-COMP.	0.16394	0.47406	0.84106	1.21696	1.59811	2.01818	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	*******	*******	*******	0.18508
Y-COMP.	*******	*******	*******	*******	*******	*******	2.09168
YAW ANGLE (DEG)....	-0.2	0.1	-0.5	-1.0	0.4	1.5	-0.1
C.G. POSITION (M)..							
X-COMP.	0.17364	0.17360	0.17999	0.18542	0.18535	0.18207	0.18509
Y-COMP.	0.02594	0.33606	0.70309	1.07904	1.46012	1.88037	2.25968

COEF. OF CUBIC POLYNOMIAL: -0.1170D 00 0.1023D 03 -0.2119D 04 0.1977D 05

FROM PONC. Y C.G. =	0.01653	0.32476	0.70309	1.08928	1.48113	1.87486	********
ERROR (M)......	-0.00941	-0.01130	0.0	0.01025	0.02101	-0.00550	********
C.G. VY (M/S) =	103.	65.	66.	50.	35.	19.	

AT T=0.0. C.G. VY= 113. ; WHEN VY=0.0. T= 0.06614 AND Y= 2.09833

PONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A= 0.0	B= 0.7216	ER=0.00369	EM= 0.0050	CD= 1.8987
STATIONS 2-5	A= 0.0	B= 0.6995	ER=0.00799	EM=-0.0108	CD= 1.8407
STATIONS 3-6	A= 0.0	B= 0.6923	ER=0.02926	EM=-0.0334	CD= 1.8217
ALL STATIONS	A= 0.0	B= 0.8179	ER=0.03320	EM=-0.0598	CD= 2.1522

STATIONS 1-4	A= 479.0	B= 0.6510	ER=0.00229	EM= 0.0032
STATIONS 2-5	A= 673.5	B= 0.5230	ER=0.00298	EM=-0.0039
STATIONS 3-6	A= 750.6	B= 0.4151	ER=0.00975	EM=-0.0117
ALL STATIONS	A= 684.5	B= 0.5334	ER=0.01260	EM= 0.0210

```
                         SHOT 118 (15-09-77 ,NO. 2)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=158. M/S
      HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6375 KG  LENGTH=0.306 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00150   0.00479   0.00981   0.01653   0.02593   0.04106   *******

NOSE POSITION (M)..
   X-COMP.          0.17735   0.13642   0.19735   0.22775   0.25131   *******   *******
   Y-COMP.          0.16516   0.51050   0.90313   1.33273   1.73472   *******   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.16008   *******   0.18148   0.21218   0.25328   *******
   Y-COMP.          *******   0.19970   *******   0.99484   1.41120   1.83874   *******

YAW ANGLE (DEG)....   0.7       4.7       3.7       7.7       6.2      -2.2      -1.2

C.G. POSITION (M)..
   X-COMP.          0.17398   0.17454   0.17958   0.20588   0.23366   0.24039   *******
   Y-COMP.          0.03120   0.37034   0.76628   1.18035   1.58882   2.00624   *******

COEF. OF CUBIC POLYNOMIAL:    -0.1240D 00    0.1113D 03    -0.2268D 04    0.2002D 05

FROM PONC. Y C.G. = 0.02255   0.35534   0.76628   1.18802   1.60776   1.99763 ********
   ERROR (M)...... -0.00865 -0.01499   0.0       0.00767   0.01894 -0.00862 ********
   C.G. VY (M/S)  =   110.       92.       73.       54.       36.       16.
   AT T=0.0.  C.G. VY= 121.      ;  WHEN  VY=0.0.  T= 0.05669  AND  Y= 2.12345

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0  B=   0.6667  ER=0.00377  EM= 0.0060  CD=  1.7592
   STATIONS 2-5    A=      0.0  B=   0.6235  ER=0.01272  EM=-0.0180  CD=  1.6453
   STATIONS 3-6    A=      0.0  B=   0.6965  ER=0.03687  EM=-0.0397  CD=  1.8379
   ALL STATIONS    A=      0.0  B=   0.7887  ER=0.04842  EM=-0.0836  CD=  2.0313

   STATIONS 1-4    A=    429.4  B=   0.6078  ER=0.00387  EM= 0.0058
   STATIONS 2-5    A=   1138.7  B=   0.3684  ER=0.00372  EM=-0.0056
   STATIONS 3-6    A=    935.2  B=   0.3998  ER=0.00600  EM=-0.0072
   ALL STATIONS    A=   1010.7  B=   0.4373  ER=0.01258  EM= 0.0189
```

SHOT 119 (15-09-77 ,NO. 3)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=146. M/S
HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6338 KG LENGTH=0.306 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00150	0.00483	0.00984	0.01655	0.02596	0.04102	*******
NOSE POSITION (M)..							
X-COMP.	0.17411	0.17348	0.17964	0.18714	0.20027	*******	*******
Y-COMP.	0.16955	0.45187	0.87884	1.27137	1.66342	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	0.18697	0.18378	*******	0.19912
Y-COMP.	*******	*******	*******	0.95211	1.33955	*******	2.10035
YAW ANGLE (DEG)....	-0.4	-0.2	-1.0	0.3	3.4	0.5	0.0
C.G. POSITION (M)..							
X-COMP.	0.17604	0.17444	0.18422	0.18706	0.19283	*******	0.19941
Y-COMP.	0.03155	0.35387	0.74092	1.12739	1.51736	*******	2.26835

COEF. OF CUBIC POLYNOMIAL: -0.1311D 00 0.1131D 03 -0.2819D 04 0.3503D 05

FROM PONC. Y C.G. =	0.02717	0.35287	0.74092	1.12973	1.50647	1.83547	********
ERROR (M).......	-0.00439	-0.00100	0.0	0.00234	-0.01090	********	********
C.G. VY (M/S) =	108.	88.	68.	49.	32.	13.	

AT T=0.0. C.G. VY= 120. ; WHEN VY=0.0. T= 0.05349 AND Y= 1.91451

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.7355 ER=0.01706 EM= 0.0255 CD= 1.9295

ALL STATIONS A= 1003.1 B= 0.5177 ER=0.00601 EM=-0.0109

SHOT 120 (15-09-77 ,NO. 4)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY= 66. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.7354 KG LENGTH=0.305 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS)......	0.00148	0.00478	0.00981	0.01652	0.02550	0.04099	*******
NOSE POSITION (M)..							
X-COMP.	0.14272	0.12798	*******	*******	*******	*******	*******
Y-COMP.	0.07966	0.26679	*******	*******	*******	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	*******	*******	*******	0.02009
Y-COMP.	*******	*******	*******	*******	*******	*******	2.06858
YAW ANGLE (DEG).....	-5.2	-5.8	0.0	0.0	0.0	0.0	2.7
C.G. POSITION (M)..							
X-COMP.	0.16999	0.15864	*******	*******	*******	*******	0.03444
Y-COMP.	-.07038	0.11740	*******	*******	*******	*******	2.22040

SHOT 121 (15-09-77 ,NO. 5)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=110. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.7359 KG LENGTH=0.305 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS)......	0.00148	0.00479	0.00983	0.01653	0.02555	0.04090	*******
NOSE POSITION (M)..							
X-COMP.	0.17855	0.18162	0.19759	0.21610	0.24230	0.24689	*******
Y-COMP.	0.14627	0.43690	0.79697	1.18842	1.58557	2.02061	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	*******	*******	*******	*******
Y-COMP.	*******	*******	*******	*******	*******	*******	*******
YAW ANGLE (DEG)....	1.6	2.6	3.5	4.4	3.9	-0.6	-2.6
C.G. POSITION (M)..							
X-COMP.	0.17030	0.16780	0.17900	0.19303	0.22160	0.25008	*******
Y-COMP.	-.00601	0.28503	0.64561	1.03767	1.43488	1.86814	*******

COEF. OF CUBIC POLYNOMIAL: -0.1421D 00 0.9616D 02 -0.1738D 04 0.1439D 05

FROM FONC. Y C.G. =	-0.01309	0.27626	0.64561	1.03727	1.44713	1.85746	*******
ERROR (M)......	-0.00708	-0.00877	0.0	-0.00041	0.01225	-0.01068	*******
C.G. VY (M/S) =	94.	81.	66.	51.	36.	19.	

AT T=0.0. C.G. VY= 101. ; WHEN VY=0.0. T= 0.06306 AND Y= 2.06642

FONCELET COEFFICIENTS BASED ON :

STATIONS 1-4	A=	0.0	B=	0.5851	ER=0.00206	EM= 0.0033	CD=	1.7821
STATIONS 2-5	A=	0.0	B=	0.5681	ER=0.01306	EM=-0.0191	CD=	1.7304
STATIONS 3-6	A=	0.0	B=	0.7026	ER=0.01750	EM=-0.0153	CD=	2.1402
ALL STATIONS	A=	0.0	B=	0.7315	ER=0.03070	EM=-0.0560	CD=	2.2281

STATIONS 1-4	A=	654.0	B=	0.4557	ER=0.00333	EM= 0.0041
STATIONS 2-5	A=	1258.6	B=	0.2393	ER=0.00388	EM=-0.0062
STATIONS 3-6	A=	470.5	B=	0.5361	ER=0.00420	EM= 0.0061
ALL STATIONS	A=	827.6	B=	0.4001	ER=0.00885	EM= 0.0122

SHOT 122 (15-09-77 ,NO. 6)

DRY SAND DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=199. M/S
SOLID FLAT NOSE PROJECTILE ; MASS=0.7354 KG LENGTH=0.305 M

X-RAY STATION......	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7
TIME (SECONDS).....	0.00148	0.00477	0.00982	0.01651	0.02594	0.04084	*******
NOSE POSITION (M)..							
X-COMP.	0.16883	0.17135	*******	*******	*******	*******	*******
Y-COMP.	0.16480	0.48305	*******	*******	*******	*******	*******
TAIL POSITION (M)..							
X-COMP.	*******	*******	*******	0.19318	0.17681	0.18003	0.18912
Y-COMP.	*******	*******	*******	0.99861	1.44389	1.92481	2.10165
YAW ANGLE (DEG)....	-0.3	0.5	0.0	-1.3	0.6	0.3	-1.8
C.G. POSITION (M)..							
X-COMP.	0.17016	0.16842	*******	0.18626	0.18000	0.18163	0.17981
Y-COMP.	0.01231	0.33058	*******	1.15095	1.59636	2.07730	2.25387

COEF. OF CUBIC POLYNOMIAL: -0.1356D 00 0.1051D 03 -0.1889D 04 0.1573D 05

FROM PONC. Y C.G. =	0.01195	0.32810	0.72923	1.15095	1.59901	2.07622	********
ERROR (M)......	-0.00036	-0.00248	********	0.0	0.00266	-0.00108	********
C.G. VY (M/S) =	104.	89.	71.	56.	40.	25.	

AT T=0.0. C.G. VY= 113. ; WHEN VY=0.0. T= 0.07754 AND Y= 2.50080

PONCELET COEFFICIENTS BASED ON :

ALL STATIONS A= 0.0 B= 0.6053 ER=0.03404 EM= 0.0617 CD= 1.8425

ALL STATIONS A= 591.7 B= 0.4448 ER=0.00190 EM= 0.0027

SHOT 123 (15-09-77 ,NO. 7)

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DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=463. M/S
SOLID STEP CONE PROJECTILE : MASS=0.5110 KG  LENGTH=0.221 M

X-RAY STATION......   NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00070   0.00302   0.00653   0.01153   0.01902   0.03528   *******

NOSE POSITION (M)..
   X-COMP.          0.17992   0.17485   0.19051   0.20806   0.23139   0.23765   *******
   Y-COMP.          0.08584   0.41960   0.80581   1.19588   1.56262   2.05709   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.17154   0.17574   0.19464   0.21752   0.24204   0.20822
   Y-COMP.          *******   0.20762   0.60625   0.98886   1.36474   1.83176   2.20966

YAW ANGLE (DEG)....   -0.6      1.1       3.2       4.7       3.8      -5.9      -3.5

C.G. POSITION (M)..
   X-COMP.          0.18235   0.17311   0.18276   0.20102   0.22411   0.23955   0.19542
   Y-COMP.          -.03013   0.30833   0.70106   1.08722   1.45876   1.93382   2.31388

COEF. OF CUBIC POLYNOMIAL:    -0.1297D 00    0.1571D 03    -0.5159D 04    0.6710D 05

FROM PONC. Y C.G. =-0.06055   0.29673   0.70106   1.11023   1.51559   1.92898 ********
   ERROR (M)...... -0.03042 -0.01161   0.0       0.02301   0.05683 -0.00984 ********
   C.G. VY (M/S)  =    176.      135.      98.       68.       42.       11.
   AT T=0.0.  C.G. VY= 193.      ;  WHEN  VY=0.0.  T= 0.04308  AND  Y= 1.97267

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0   B=   0.8500  ER=0.00848  EM=-0.0131  CD=  1.7978
   STATIONS 2-5    A=      0.0   B=   0.9163  ER=0.01375  EM=-0.0175  CD=  1.9382
   STATIONS 3-6    A=      0.0   B=   0.8495  ER=0.05974  EM=-0.0689  CD=  1.7968
   ALL STATIONS    A=      0.0   B=   1.0126  ER=0.07556  EM=-0.1282  CD=  2.1418

   STATIONS 1-4    A=   2963.1   B=   0.5830  ER=0.00311  EM=-0.0052
   STATIONS 2-5    A=   2546.5   B=   0.5785  ER=0.00371  EM=-0.0044
   STATIONS 3-6    A=   1511.5   B=   0.4929  ER=0.02732  EM=-0.0339
   ALL STATIONS    A=   1422.8   B=   0.6775  ER=0.03136  EM= 0.0568
```

SHOT 124 (15-09-77 ,NO. 9)

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DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=571. M/S
SOLID STEP CONE PROJECTILE ; MASS=0.5110 KG  LENGTH=0.221 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00070   0.00302   0.00653   0.01147   0.01904   0.03509   *******

NOSE POSITION (M)..
   X-COMP.          *******   0.16610   0.15582   0.11129   0.02521   *******   *******
   Y-COMP.          *******   0.41968   0.81286   1.21387   1.60900   *******   *******

TAIL POSITION (M)..
   X-COMP.          *******   *******   0.18703   0.16109   0.09313   *******   *******
   Y-COMP.          *******   *******   0.80125   1.01764   1.42034   *******   *******

YAW ANGLE (DEG)....   -1.2      -2.1      -8.2     -13.3     -19.9       1.0       0.0

C.G. POSITION (M)..
   X-COMP.          *******   0.16995   0.17220   0.13743   0.06086   *******   *******
   Y-COMP.          *******   0.30374   0.70179   1.11087   1.50997   *******   *******

COEF. OF CUBIC POLYNOMIAL:   -0.1261D 00    0.1575D 03    -0.5194D 04    0.7531D 05

FROM FCNC. Y C.G. =-0.02975  0.30153  0.70179  1.11354  1.50905  1.69212 ********
   ERROR (M)....... ******** -0.00181  0.0      0.00267 -0.00093 ******** ********
   C.G. VY (M/S)  =   158.     130.      99.      69.      37.     *****
   AT T=0.0.  C.G. VY= 169.     ;  WHEN  VY=0.0.  T= 0.03077  AND  Y= 1.72010

FORCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=     0.0  B=  0.9521  ER=0.01694  EM=-0.0260  CD=  2.0139

   ALL STATIONS   A=  2975.3  B=  0.4453  ER=0.00194  EM= 0.0027
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SHOT 126 (15-09-77 ,NO.10)

DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=160. M/S
HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6338 KG  LENGTH=0.306 M

X-RAY STATION......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00150  0.00482  0.00979  0.01654  0.02590  0.04109  *******

NOSE POSITION (M)..
   X-COMP.          0.17269  0.17903  0.18932  0.20111  0.21822  *******  *******
   Y-COMP.          0.13021  0.36436  0.70365  1.04626  1.41247  *******  *******

TAIL POSITION (M)..
   X-COMP.          *******  *******  *******  *******  *******  *******  0.24658
   Y-COMP.          *******  *******  *******  *******  *******  *******  2.01428

YAW ANGLE (DEG)....   1.2      1.6      2.6      2.6      3.4      0.0     -2.1

C.G. POSITION (M)..
   X-COMP.          0.16691  0.17154  0.17705  0.18884  0.20188  *******  0.23457
   Y-COMP.          -.00767  0.24656  0.56620  0.90881  1.27544  *******  2.18185

COEF. OF CUBIC POLYNOMIAL :  -0.1344D 00    0.8723D 02   -0.1804D 04    0.2079D 05

FROM PONC. Y C.G. =-0.01452  0.24500  0.56620  0.90788  1.25671  1.61071 ********
   ERROR (M)...... -0.00685 -0.00157  0.0     -0.00092 -0.01873 ******** ********
   C.G. VY (M/S)  =    85.       72.      58.      44.      31.      16.
   AT T=0.0.  C.G. VY=  92.      ;  WHEN  VY=0.0.  T= 0.06389  AND  Y= 1.79197

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS   A=     0.0  B=  0.6961  ER=0.00698  EM=-0.0103  CD=  1.8261

   ALL STATIONS   A=   675.3  B=  0.5201  ER=0.01002  EM=-0.0187
```

```
                              SHOT 127 (15-09-77 ,NO.11)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=197. M/S
     SOLID FLAT NOSE PROJECTILE ; MASS=0.9193 KG  LENGTH=0.381 M

X-RAY STATION......   NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00089  0.00501  0.01050  0.01707  0.01772  0.04512  *******

NOSE POSITION (M)..
   X-COMP.          0.17263  0.17923  0.19557  *******  *******  *******  *******
   Y-COMP.          0.09145  0.48188  0.91144  *******  *******  *******  *******

TAIL POSITION (M)..
   X-COMP.          *******  *******  *******  *******  0.20316  0.25014  0.25683
   Y-COMP.          *******  *******  *******  *******  1.43028  2.03872  2.05413

YAW ANGLE (DEG)....   1.8      1.9      3.2      3.3      2.5     -1.5     -1.9

C.G. POSITION (M)..
   X-COMP.          0.16067  0.16660  0.17434  *******  0.21943  0.24017  0.24420
   Y-COMP.          -.05867  0.29180  0.72213  *******  1.62008  2.22896  2.24421

COEF. OF CUBIC POLYNOMIAL:    -0.1230D 00    0.5111D 02    0.4284D 04   -0.9445D 05

FROM POLY. Y C.G. =-0.50739  0.06229  0.72213  1.36240  1.41742  2.27482 ********
   ERROR (M)...... -0.40872 -0.22951  0.0     ******** -0.20267  0.04586 ********
   C.G. VY (M/S)  =   146.     130.     110.      85.      83.    *****
   AT T=0.0.  C.G. VY= 149.      ;  WHEN  VY=0.0.  T= 0.03976  AND  Y= 2.32885

PONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=     0.0  B=  0.4889  ER=0.49664  EM=-0.6645  CD=  1.3597

   ALL STATIONS    A=  3753.9  B=  0.0003  ER=0.25637  EM=-0.4087
```

SHOT 128 (16-09-77 ,NO. 1)

```
DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=262. M/S
HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6375 KG  LENGTH=0.306 M

X-RAY STATION......    NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00149   0.00480   0.00975   0.01650   0.02585   0.04112   *******

NOSE POSITION (M)..
   X-COMP.          0.17102   0.17669   0.19065   0.20192   0.22212   0.22744   *******
   Y-COMP.          0.17453   0.50738   0.89256   1.28764   1.68338   2.10450   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.15995   0.15555   0.17010   0.19040   0.22199   0.23247
   Y-COMP.          *******   0.20496   0.57254   0.97487   1.38527   1.80010   2.10811

YAW ANGLE (DEG)....    0.2       2.7       7.0       7.0       6.1       2.1      -2.6

C.G. POSITION (M)..
   X-COMP.          0.17006   0.16914   0.17482   0.18757   0.20781   0.22498   0.21754
   Y-COMP.          0.03653   0.37099   0.74824   1.14659   1.54894   1.96725   2.27544

COEF. OF CUBIC POLYNOMIAL:    -0.1107D 00     0.1077D 03    -0.2200D 04     0.1970D 05

FROM PONC. Y C.G. = 0.02835   0.35436   0.74824   1.15860   1.56484   1.95571 ********
   ERROR (M)...... -0.00818 -0.01664   0.0       0.01201   0.01590 -0.01154 ********
   C.G. VY (M/S)  =    108.       90.       70.       52.       36.       17.
   AT T=0.0.   C.G. VY= 118.     ;  WHEN  VY=0.0.  T= 0.05898  AND  Y= 2.10257

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0  B=   0.7415  ER=0.00336  EM= 0.0056   CD=  1.9567
   STATIONS 2-5    A=      0.0  B=   0.6505  ER=0.00803  EM=-0.0110   CD=  1.7165
   STATIONS 3-6    A=      0.0  B=   0.6572  ER=0.04162  EM=-0.0435   CD=  1.7341
   ALL STATIONS    A=      0.0  B=   0.8049  ER=0.04242  EM=-0.0734   CD=  2.1239

   STATIONS 1-4    A=    224.1  B=   0.7024  ER=0.00382  EM= 0.0059
   STATIONS 2-5    A=    875.7  B=   0.4397  ER=0.00154  EM=-0.0019
   STATIONS 3-6    A=   1086.0  B=   0.2905  ER=0.00989  EM=-0.0129
   ALL STATIONS    A=    899.4  B=   0.4747  ER=0.01322  EM=-0.0166
```

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                                SHOT 129 (16-09-77 ,NO. 2)

     DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=415. M/S
     HOLLOW FLAT NOSE PROJECTILE ; MASS=0.6354 KG  LENGTH=0.306 M

X-RAY STATION......     NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECONDS)..... 0.00148   0.00479   0.00976   0.01648   0.02588   0.04115   *******

NOSE POSITION (M)..
   X-COMP.          0.17256   0.17732   0.19090   0.20357   0.22435   0.22778   *******
   Y-COMP.          0.16010   0.47778   0.85165   1.23597   1.61774   2.03824   *******

TAIL POSITION (M)..
   X-COMP.          *******   0.15728   0.15321   0.16746   0.19208   0.23204   0.23267
   Y-COMP.          *******   0.17536   0.54811   0.93212   1.31978   1.81958   2.09608

YAW ANGLE (DEG)....   0.9       3.9       7.3       7.6       6.2      -3.6      -1.6

C.G. POSITION (M)..
   X-COMP.          0.16823   0.16328   0.17390   0.18729   0.20980   0.22970   0.22358
   Y-COMP.          0.02217   0.34139   0.71476   1.09894   1.48337   1.93963   2.26383

COEF. OF CUBIC POLYNOMIAL:    -0.12620 00     0.10650 03    -0.23090 04     0.2286D 05

FROM PONC. Y C.G. = 0.00583   0.33138   0.71476   1.10991   1.51131   1.93279 ********
   ERROR (M)....... -0.01234 -0.01002   0.0       0.01097   0.02795  -0.00684 ********
   C.G. VY (M/S)  =   108.       88.       68.       51.       36.       21.
   AT T=0.0. C.G. VY= 120.      :  WHEN  VY=0.0.  T= 0.07484  AND  Y= 2.25862

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0  B=   0.7156  ER=0.00382  EM= 0.0056  CD=   1.3822
   STATIONS 2-5    A=      0.0  B=   0.7138  ER=0.00834  EM=-0.0112  CD=   1.3775
   STATIONS 3-6    A=      0.0  B=   0.6877  ER=0.02115  EM=-0.0271  CD=   1.3088
   ALL STATIONS    A=      0.0  B=   0.7928  ER=0.02883  EM=-0.0523  CD=   2.0852

   STATIONS 1-4    A=    476.2  B=   0.6436  ER=0.00154  EM= 0.0023
   STATIONS 2-5    A=    710.2  B=   0.5393  ER=0.00380  EM=-0.0045
   STATIONS 3-6    A=    489.5  B=   0.5147  ER=0.01121  EM=-0.0124
   ALL STATIONS    A=    538.8  B=   0.5782  ER=0.01550  EM= 0.0279
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                         SHOT 130 (16-09-77 ,NO. 3)

      DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=333. M/S
      HOLLOW FLAT NOSE PROJECTILE ; MASS=0.0333 KG  LENGTH=0.306 M

 X-RAY STATION......  NO.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

 TIME (SECONDS)..... 0.00149   0.00480   0.00977   0.01651   0.02598   0.04118   *******

 NOSE POSITION (M)..
    X-COMP.          0.16965   0.17412   0.18096   0.19156   0.20385   0.21051   *******
    Y-COMP.          0.16821   0.45611   0.87431   1.27202   1.66835   2.10578   *******

 TAIL POSITION (M)..
    X-COMP.          *******   0.16262   0.16811   0.17250   0.18506   0.20119   0.24286
    Y-COMP.          *******   0.19349   0.56101   0.96498   1.34887   1.78268   2.04525

 YAW ANGLE (DEG)....   0.5       2.4       3.8       4.4       4.5       1.9      -0.4

 C.G. POSITION (M)..
    X-COMP.          0.16748   0.16893   0.17516   0.18302   0.19538   0.20636   0.24091
    Y-COMP.          0.03023   0.35828   0.73302   1.13351   1.52427   1.96007   2.21324

 COEF. OF CUBIC POLYNOMIAL:    -0.1185D 00    0.1074D 03    -0.2241D 04    0.2086D 05

 FROM PONC. Y C.G. = 0.02104   0.34296   0.73302   1.13939   1.54739   1.95460  *******
    ERROR (M)...... -0.00919 -0.01532   0.0       0.00588   0.02311  -0.00547  *******
    C.G. VY (M/S)   =   107.       89.       70.       52.       36.       18.
    AT T=0.0.  C.G. VY= 117.      ;  WHEN  VY=0.0.   T= 0.06314  AND  Y= 2.15044

 PONCELET COEFFICIENTS BASED ON :

    STATIONS 1-4     A=      0.0  B=   0.7081  ER=0.00375  EM= 0.0060  CD=  1.8578
    STATIONS 2-5     A=      0.0  B=   0.6358  ER=0.01330  EM=-0.0191  CD=  1.6681
    STATIONS 3-6     A=      0.0  B=   0.7302  ER=0.02147  EM=-0.0261  CD=  1.9157
    ALL STATIONS     A=      0.0  B=   0.7922  ER=0.03801  EM=-0.0672  CD=  2.0784

    STATIONS 1-4     A=    123.5  B=   0.6890  ER=0.00407  EM= 0.0060
    STATIONS 2-5     A=   1243.6  B=   0.3313  ER=0.00342  EM=-0.0053
    STATIONS 3-6     A=    542.5  B=   0.5439  ER=0.00503  EM=-0.0072
    ALL STATIONS     A=    786.2  B=   0.4914  ER=0.01355  EM= 0.0231
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```
                         SHOT 131 (16-09-77 ,NO. 4)

   DRY SAND  DENSITY= 1538 KG/M**3 ; APPROACH VELOCITY=264. M/S
   SOLID FLAT NOSE PROJECTILE ; MASS=0.7362 KG  LENGTH=0.305 M

X-RAY STATION......    NC.1      NO.2      NO.3      NO.4      NO.5      NO.6      NO.7

TIME (SECCNDS)..... 0.00149   0.00479   0.00978   0.01653   0.02586   0.04124   *******

NOSE POSITICN (M)..
   X-CCMP.          0.17411   0.17721   0.19058   0.20871   0.23526   *******   *******
   Y-CCMP.          0.15566   0.47395   0.86061   1.27381   1.68745   *******   *******

TAIL PCSITICN (M)..
   X-CCMP.          *******   0.16355   0.15457   0.16498   0.19659   0.25469   0.23802
   Y-COMP.          *******   0.16175   0.56168   0.95980   1.38147   1.84117   2.11642

YAW ANGLE (DEG)....    0.3       2.6       5.6       8.5       7.5      -1.1      -0.2

C.G. POSITICN (M)..
   X-CCMP.          0.17278   0.17058   0.17258   0.18655   0.21593   0.24884   0.23722
   Y-COMP.          0.00317   0.31785   0.71115   1.11681   1.53446   1.93356   2.26892

COEF. OF CUBIC POLYNOMIAL:   -0.1472D 00    0.1056D 03   -0.2033D 04    0.1771D 05

FRCM FCNC. Y C.G. =-0.00841   0.31390   0.71115   1.12824   1.54902   1.98019 ********
   ERROR (M)...... -0.01157 -0.00395   0.0       0.01143   0.01456 -0.01336 ********
   C.G. VY (M/S)  =    107.       90.       71.       54.       38.       20.
   AT T=0.0.  C.G. VY= 116.      ;  WHEN  VY=0.0,  T= 0.06473  AND  Y= 2.20372

FCNCELET CCEFFICIENTS BASED ON :

   STATIONS 1-4    A=      0.0   B=   0.6196  ER=0.00472  EM=-0.0069   CD=  1.3880
   STATIONS 2-5    A=      0.0   B=   0.6561  ER=0.00468  EM=-0.0055   CD=  1.9993
   STATIONS 3-6    A=      0.0   B=   0.5863  ER=0.04373  EM=-0.0465   CD=  1.7866
   ALL STATIONS    A=      0.0   B=   0.7399  ER=0.03354  EM=-0.0634   CD=  2.2546

   STATIONS 1-4    A=    782.9   B=   0.4621  ER=0.00405  EM= 0.0062
   STATIONS 2-5    A=    660.0   B=   0.5071  ER=0.00196  EM=-0.0024
   STATIONS 3-6    A=   1141.0   B=   0.2266  ER=0.01577  EM=-0.0222
   ALL STATIONS    A=    782.9   B=   0.4621  ER=0.01158  EM= 0.0146
```

```
                         SHOT 132 (16-09-77 ,NO. 5)

    DRY SAND  DENSITY= 1538 KG/M**3 : APPROACH VELOCITY=206. M/S
    SOLID FLAT NOSE PROJECTILE ; MASS=0.7354 KG  LENGTH=0.305 M

X-RAY STATION......     NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00149  0.00478  0.00977  0.01646  0.02575  0.04096  *******

NOSE POSITION (M)..
   X-COMP.          0.15785  0.15199  0.15034  0.14221  0.13188  *******  *******
   Y-COMP.          0.15140  0.46323  0.84582  1.25917  1.67760  *******  *******

TAIL POSITION (M)..
   X-COMP.          *******  *******  0.17168  0.15996  0.15318  0.13073  0.12027
   Y-COMP.          *******  *******  0.52207  0.93526  1.36550  1.86482  1.99440

YAW ANGLE (DEG)....    -2.0     -2.3     -3.5     -2.5     -3.6     -2.1     -0.9

C.G. POSITION (M)..
   X-COMP.          0.16822  0.16355  0.16101  0.15109  0.14253  0.11983  0.11575
   Y-COMP.          -.00075  0.31120  0.68395  1.09722  1.52155  2.01693  2.14683

COEF. OF CUBIC POLYNOMIAL:   -0.1435D 00    0.1017D 03    -0.1856D 04    0.1614D 05

FROM PONC. Y C.G. =-0.00722  0.29741  0.68395  1.09873  1.53389  2.00454 ********
   ERROR (M)...... -0.00647 -0.01379  0.0      0.00152  0.01234 -0.01239 ********
   C.G. VY (M/S)  =   100.     86.      70.      55.      40.      23.
   AT T=0.0.  C.G. VY= 107.       :  WHEN  VY=0.0.  T= 0.07110  AND  Y= 2.[illegible]3655

PONCELET COEFFICIENTS BASED ON :

   STATIONS 1-4   A=     0.0  B=  0.5927  ER=0.00492  EM= 0.0068  CD=  1.8043
   STATIONS 2-5   A=     0.0  B=  0.5112  ER=0.01173  EM=-0.0172  CD=  1.5551
   STATIONS 3-6   A=     0.0  B=  0.6196  ER=0.01343  EM=-0.0152  CD=  1.8860
   ALL STATIONS   A=     0.0  B=  0.6559  ER=0.02497  EM=-0.0448  CD=  1.9964

   STATIONS 1-4   A=     0.0  B=  0.5949  ER=0.00494  EM= 0.0067
   STATIONS 2-5   A=     0.0  B=  0.5949  ER=0.03288  EM=-0.0404
   STATIONS 3-6   A=   371.1  B=  0.5032  ER=0.00397  EM= 0.0056
   ALL STATIONS   A=   698.5  B=  0.4105  ER=0.01039  EM=-0.0138
```

```
                              SHOT 133 (16-09-77 ,NO. 6)

       WATER                             : APPROACH VELOCITY=391. M/S
       SOLID STEP CONE PROJECTILE ; MASS=0.5104 KG   LENGTH=0.221 M

X-RAY STATION......    NO.1     NO.2     NO.3     NO.4     NO.5     NO.6     NO.7

TIME (SECONDS)..... 0.00022  0.00057  0.00196  0.00367  0.00551  0.00789  *******

NOSE POSITION (M)..
   X-COMP.          *******  0.17501  0.18592  *******  *******  *******  *******
   Y-COMP.          *******  0.33673  0.71192  *******  *******  *******  *******

TAIL POSITION (M)..
   X-COMP.          *******  *******  *******  0.16514  0.21910  *******  *******
   Y-COMP.          *******  *******  *******  1.11262  1.68458  *******  *******

YAW ANGLE (DEG)....    0.0      1.3      2.1      8.0     12.2      0.0      0.0

C.G. POSITION (M)..
   X-COMP.          *******  0.16975  0.17753  0.19491  0.26231  *******  *******
   Y-COMP.          *******  0.22085  0.59622  1.21360  1.78028  *******  *******

COEF. OF CUBIC POLYNOMIAL:      -0.1378D 00     0.3647D 03     0.8988D 04   -0.2172D 07

FROM FCNC. Y C.G. =-0.16989  0.18895  0.59622  1.16123  1.64796  2.15742 ********
   ERROR (M)...... ******** -0.03190  0.0     -0.05237 -0.13230 ******** ********
   C.G. VY (M/S)  =    520.     446.     375.     294.     239.     192.
   AT T=0.0.   C.G. VY= 547.      ;  WHEN  VY=0.0.  T=14.21192  AND   Y=17.60420

FONCELET COEFFICIENTS BASED ON :

   ALL STATIONS    A=       0.0  B=  0.6196  ER=0.01343  EM=-0.0152  CD=  1.8860

   ALL STATIONS    A=       0.0  B=  0.4281  ER=0.08419  EM=-0.1323
```

APPENDIX B - NONLINEAR REGRESSION PROCEDURE (MARQUARDT ALGORITHM)

The Marquardt algorithm is a method of fitting a multiparameter nonlinear function to experimental data; see references [6,7]. Before using it to fit the data of the Eglin experiments, the two-parameter Equation (2) of Section 1.4 was simplified as follows. Let $Y=y-y_0$, $T=t-t_0$, $D=\sqrt{AB}$. (B-1) The Equation (2) predicts for each X-Ray firing time T_i

$$\bar{Y}_i = \frac{1}{B}\ell n\{\cos DT_i + \frac{B}{D}V_o \sin DT_i\} \tag{B-2}$$

where the overbar on $\bar{Y}_i$ is used to distinguish it from the experimental value Y_i. The problem is to choose B and D so as to minimize the sum

$$S_1 = \sum_{i=1}^{N} (Y_i - \bar{Y}_i)^2 \tag{B-3}$$

The Marquardt procedure solves the nonlinear regression iteratively by a sequence of linear regressions. With some assumed values for B and D a corrected position $\hat{Y}_i$ is determined by retaining only the linear terms in a Taylor's series expansion

$$\hat{Y}_i = \bar{Y}_i^* + \left(\frac{\partial \bar{Y}_i}{\partial B}\right)^* \Delta B + \left(\frac{\partial \bar{Y}_i}{\partial D}\right)^* \Delta D \tag{B-4}$$

where the asterisks denote quantities evaluated with the previously assumed values of B and D, and the changes ΔB and ΔD are to be determined. A new sum $\hat{S}$ is formed,

$$\hat{S} = \sum_{i=1}^{N} (Y - \hat{Y}_i)^2 \tag{B-5}$$

and ΔA and ΔB are sought to minimize the sum by simultaneous solution of the two equations

$$\partial\hat{S}/\partial(\Delta B) = 0 \qquad \partial\hat{S}/\partial(\Delta D) = 0 \tag{B-6}$$

which are linear in ΔB and ΔD.

This would lead to the following matrix equation if the parameter λ in the matrix were zero

$$\begin{bmatrix} \lambda + \Sigma\left(\frac{\partial \bar{Y}_i}{\partial B}\right)^2 & \Sigma\frac{\partial \bar{Y}_i}{\partial B}\ \frac{\partial Y_i}{\partial D} \\ \Sigma\frac{\partial \bar{Y}_i}{\partial B}\ \frac{\partial \bar{Y}_i}{\partial D} & \lambda + \Sigma\left(\frac{\partial \bar{Y}_i}{\partial D}\right)^2 \end{bmatrix}^* \begin{bmatrix} \Delta B \\ \Delta D \end{bmatrix} = \begin{bmatrix} \Sigma\left(\frac{\partial \bar{Y}_i}{\partial B}\right)^* (Y_i - \bar{Y}_i^*) \\ \Sigma\left(\frac{\partial \bar{Y}_i}{\partial D}\right)^* (Y_i - \bar{Y}_i^*) \end{bmatrix} \qquad \text{(B-7)}$$

With $\lambda = 0$, the procedure is the Gauss-Newton algorithm. In the Marquardt algorithm convergence is improved by starting with some nonzero value for λ, and then decreasing it if successive iterations produce smaller values of the sum S_1 of Equation (B-3). After a solution for ΔB and ΔD, the values of B and D are updated to $B + \Delta B$ and $D + \Delta D$ to be used as new initial values in evaluating the quantities.

Figure B-1 is a simplified version of the flow chart for the computer program. In the present calculations, starting values of $\lambda=1$, $B_o=0.5m^{-1}$ and $A_o=4000m/s^2$ [so that $D_o=\sqrt{2000}$] were used. When the iteration reduces the value of S_1, the parameter λ is reduced to λ/C and another iteration performed. The factor C=5 was used in this calculation. The iterations were continued until one of the two following criteria was satisfied: either $S_1<\epsilon_1$ or $|(S_1)_n - (S_1)_{n-1}|<\epsilon_2$ in successive iterations. The convergence parameters used were $\epsilon_1=0.00005$ and $\epsilon_2=0.0000001$. Note that in the flow chart the symbols S1 and S2 both refer to the sum S_1 formed as in Equation (B-3). In a few cases the initial guess satisfied $S2<\epsilon_2$, and the printed tabulation shows A=4000, B=0.5.

The procedure used for fitting with one parameter, after setting A=0 or A equal to a nonzero constant value was a trivial modification of that outlined above for the two-parameter version.

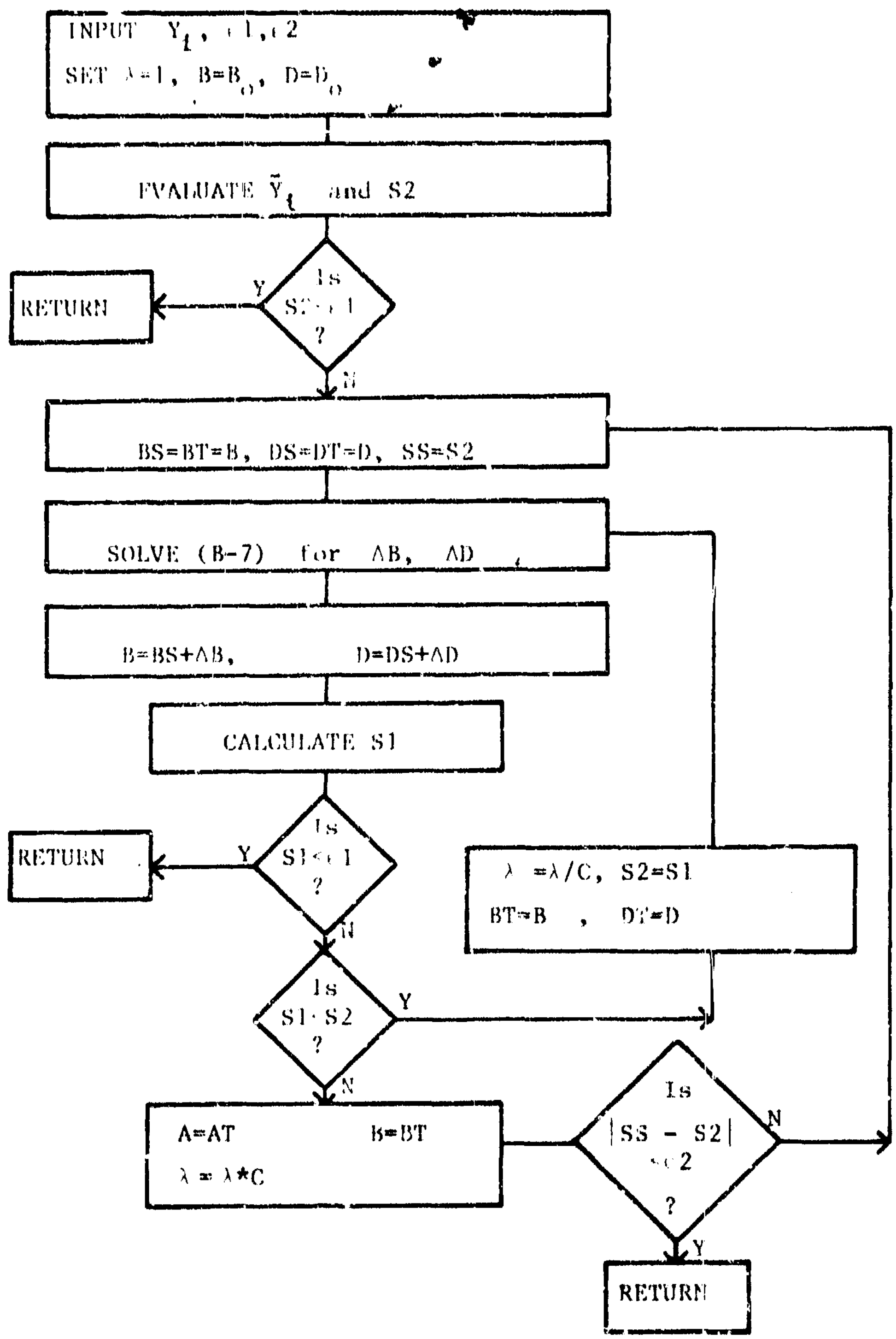

Figure B-1 Two-Parameter Nonlinear Regression Logic Diagram